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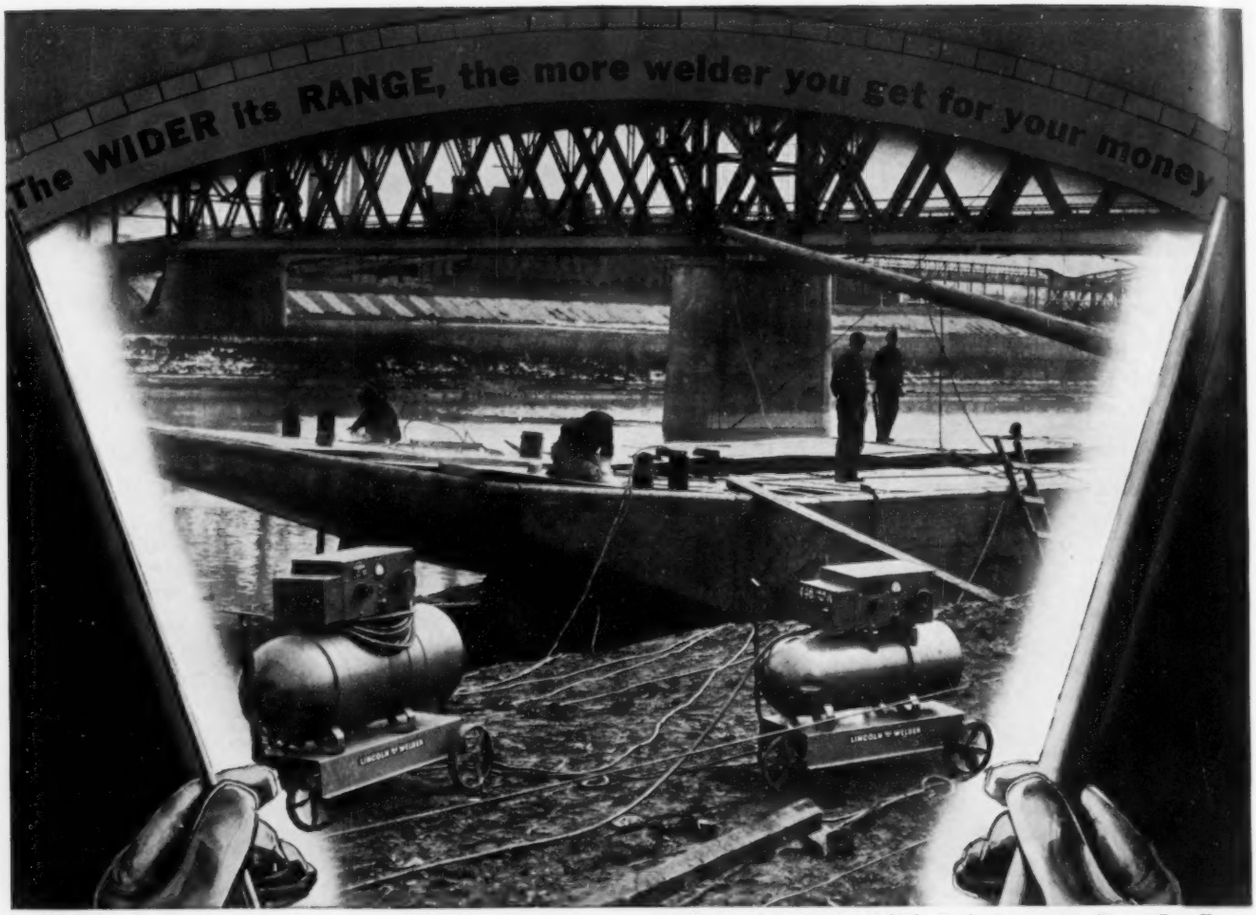

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Welded Structures for Hydraulic Turbines*

By GEORGE A. JESSOP†

FACED with the task of building this country's largest and the world's most powerful Kaplan or automatic adjustable blade turbines, thorough consideration was given to the use of castings, welded plate and composite construction consisting of plate and steel castings welded together. The proposed turbines were very much larger than anything heretofore attempted but a background of many years of experience with welded members was available and it was decided to fabricate many of the pieces for which castings had always been used before. Without this background of shop and field experience, it would have been inadvisable to attempt the carrying out of the ideas in mind.

For a proper understanding of the problems involved and of the nature of the work which must be performed by the finished product, it will be necessary to consider briefly the operation and size of the equipment. Figure 1 shows a section through the power house as a whole with the concrete supply and discharge passages. There are two units each consisting of a generator and turbine capable of developing 66,000 hp. at a head of 46 ft., but built to operate successfully under a head as high as 69 ft., the minimum head being 30 ft. The speed of the unit is 75 r.p.m.

Figure 2 shows a section through the turbine gate casing. The diameter over the speed or stay vane is 36 ft. 6 in. The diameter of the Kaplan runner is 23 ft. 4 in. and the diameter of the main shaft is 39 in. The weight of the runner hub alone is 100,000 lb. and each of the five runner blades 27,000 lb. The speed ring weighs 177,000 lb. and is split into five parts for handling and shipment.

It was quickly and easily determined that the runner hub, the blades or buckets of the turbine, the cross head, the blade rocker arms and outer bearing supports should be made of cast steel some of these pieces being of special alloys. The deflector, together with the guide bearing mounted therein, is made of cast iron. The revolving blade servo motor and its piston are steel castings.

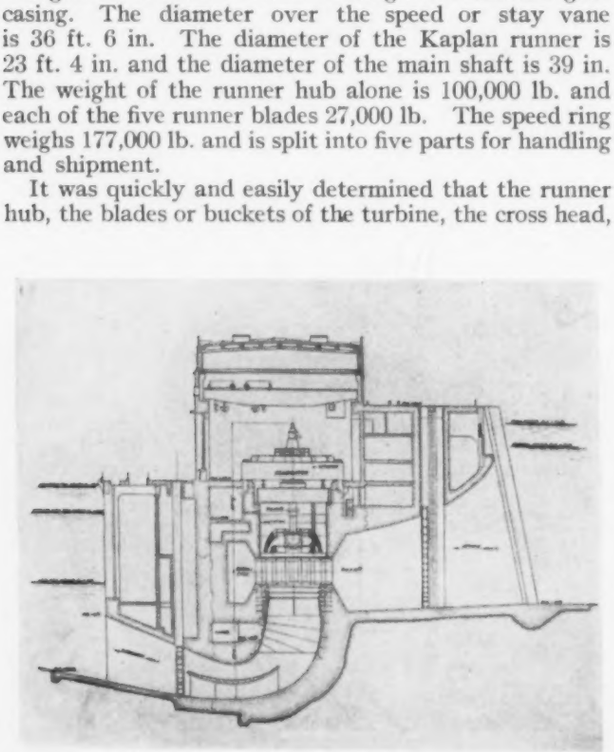


Fig. 1—Cross Section Through Power House

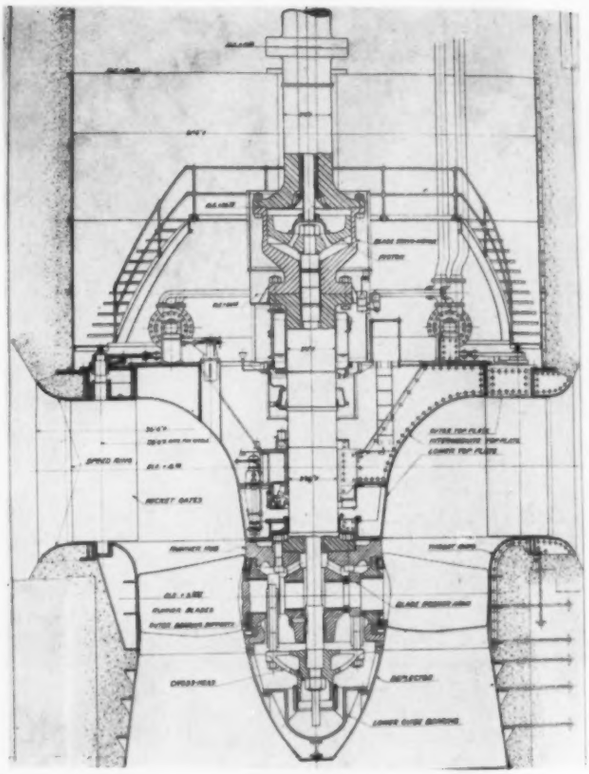


Fig. 2—Vertical Section Through 280 In. Kaplan Turbine

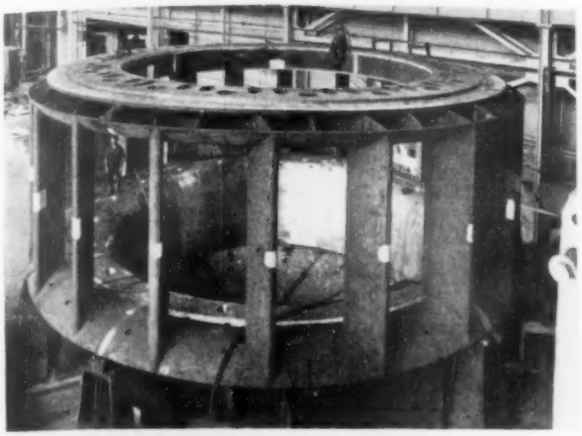
For a number of other parts, quite some consideration was necessary to determine the most economical type of fabrication.

It appeared that for the welded plate or composite members, a number of advantages could be realized. There was an elimination of a very large percentage of patterns, part of which advantage, however, was lost because of the necessity for having a number of dies, but nevertheless a substantial saving in expense and a still greater saving in the volume of storage required was evident. The various pieces of equipment could be gotten into the shop more quickly so that machining and assembly could proceed. There was almost absolute assurance that machine work would not expose defects with resultant rejection, replacement and delay. There were substantial penalties specified for late delivery hence it was doubly important to be able to set and follow an exact schedule. The weights could be more exactly figured, thus assisting in holding to accurate estimates of cost, and machining time could be cut to a minimum. It was also possible to compute the cost of the welding,

* Presented at March 2, 1937 Meeting, New York Section, AMERICAN WELDING SOCIETY.

† Chief Engineers, S. Morgan Smith Company.

Fig. 3—Throat Ring, Outer Top Plate and Stay Vane Ring



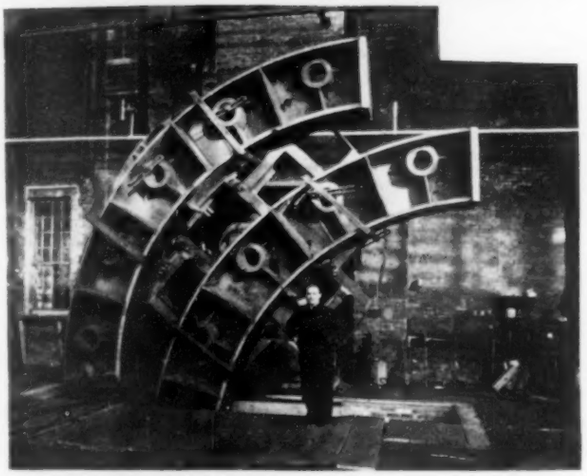


Fig. 4—Two Partly Assembled Quarters of Outer Top Plate on Horizontal Positioning Machine

assembling and handling very accurately, although in this instance, because of the unusual size, some misgivings were felt in regard to contingency. The concern was principally over the possibility of distortion. Many of the pieces were so large and strong that it was realized that it would be extremely difficult, if not impossible, to straighten them after complete fabrication.

A very careful study was made by the designers, shop superintendents and welders, including a thorough analysis of each part. Because of the double curvature required on many of the surfaces, the need for including a large number of bearing supports and other special features of design, the use of steel castings in conjunction with the plate was a natural thought.

Looking at the throat ring surrounding the runner, it will be seen that the upper part contains a large surface with a double curvature. This ring is also shown in Fig. 3. If made of plate, this upper part must be formed in a number of pieces which are welded together. There are also 20 bosses required for the lower gate stem bearing bushings and it will be noted there is a renewable wearing plate set in at the top of the throat ring. The decision was reached to make the upper part of the throat ring—that part outside of arrow No. 1—of cast steel and the rest, including the ribs, of plate. Die formed plates, hot pressed, were used for the double curvature section. For turbines of smaller size, it has been found more economical to carry the casting down to the vertical part of the throat ring; that is, to arrow No. 2.

Very thorough study was also made of the advisability of using castings for all or part of the outer top plate, Figs. 2 and 4. These pieces could be made with flat plates and with vertical members rolled with a constant radius, but it was necessary to have bosses for the upper gate stem bushings and to have a steel removable wearing plate set in the lower or water surface. Estimates were made for a number of combinations but it was finally found economical to use castings or forgings only for the gate stem bosses.

This outer top plate was made in four pieces for shipping and handling. Figure 4 shows two of the quarters mounted on a large revolving and tilting machine designed and built by the manufacturer. Figure 5 shows a small section of the top plate on a small universal tilting table with one of the cast bosses being welded in position. Figure 6 shows an omnigraph cutting access holes of special shape in the cover plate, this plate being $3\frac{1}{2}$ in. thick. The weight of the four pieces forming the whole is 107,000 lb.

One of the most interesting members is the speed or stay vane ring made in five sections. This is the outer structure shown in Fig. 2. This ring is divided into five parts for shipment and handling, the total weight being 177,000 lb. The series of 20 vanes act as columns

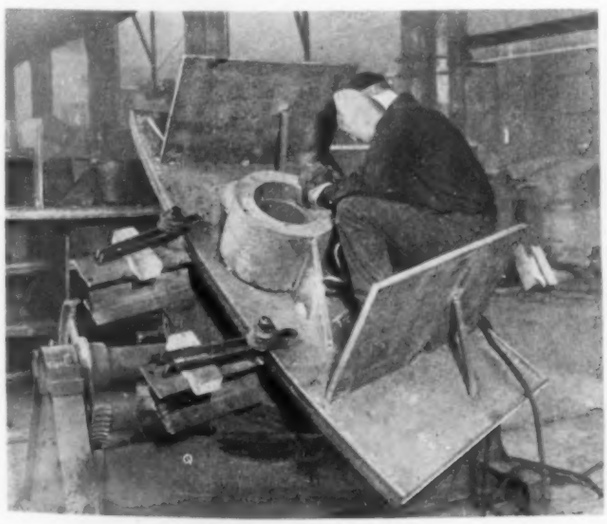


Fig. 5—Small Section of Outer Top Plate

Fig. 6—Omnigraph Cutting Holes Through $3\frac{1}{2}$ In. Plate

and carry about 9,000,000 lb. of dead load when the scroll is empty. They also act as tension members for certain parts of the scroll when under the most severe pressure conditions. These vanes are shaped to guide the water properly toward the wicket gates but because of the special hydraulic conditions imposed by the supply passages it is necessary to have a number of them specially shaped. The vanes are made with two $1^1/_4$-in. plates, hot formed to the proper shape, welded together at the back or outside edge, and welded to a nose piece at the front or inner edge, this nose piece being properly shaped by machining from bar stock. One of these vanes is well shown by Fig. 7 which also shows the use of the radiograph for cutting.

The upper and lower rings of the speed ring were first built separately, using the large positioning machine, then the vanes were welded to these rings as shown by Fig. 8. The sections of the speed ring could not be placed on the positioning machine, but by means of a shaft, blocking and the overhead cranes each section was properly placed and handled for position welding.

The two inner top plates are shown by Fig. 9. A large part of these pieces were made up of hot die pressed plates welded together. Each of these plates, it will be noted, has a double curvature. Figure 10 shows another view of this top plate with its T-section ribs and with the main turbine bearing in place.

The gate or shifting ring is also made entirely of welded plate and is shown on the large positioning machine in Fig. 11. Most of this ring could be position welded on the floor, and was placed on the positioning machine for the circumferential welds only. For small turbines it is usually found economical to cast this ring. For medium size turbines a combination structure is more often the cheapest.

One of the most interesting studies to determine the advantages of welded or cast construction is the wicket gates or adjustable guide vanes, of which there are 20 for each unit (See Fig. 12). For this large installation, it was decided to use steel castings. The gates are somewhat tapered toward the bottom and in addition welded gates require dies and also certain special operations so that as a whole the advantages seemed to favor the castings. The decision on these gates was rather contrary to the usual trend, which has been that the larger the structure the more parts can be economically made of welded construction.

For smaller wicket gates it has more often than not been found advisable to weld together pressed plates and rods or bars. Figure 13 shows a welded gate to be used for a much smaller turbine and under lower head. The stems are comparatively less in diameter, the walls are lighter and an additional stiffening rib is not required. The plates are hot pressed, welded together at the point

Fig. 7—Radiograph Trimming Stay Vane

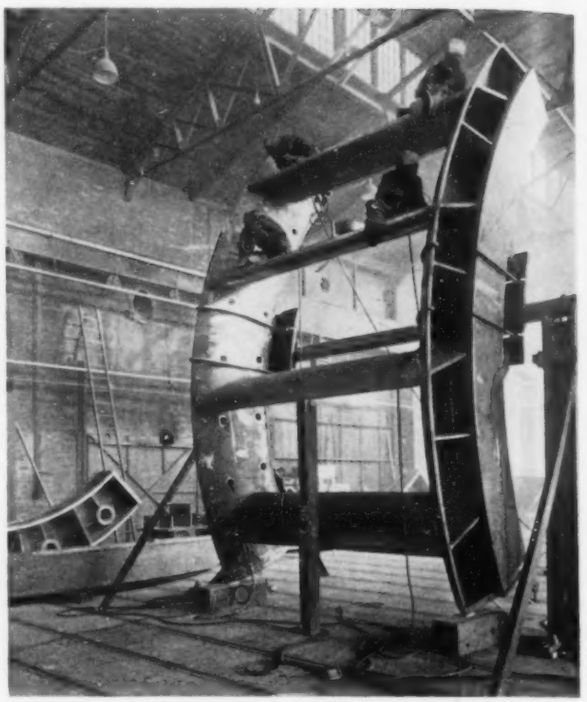


Fig. 8—Section of Stay Vane Ring

and back and to the stem in three lengths at the top, middle and bottom.

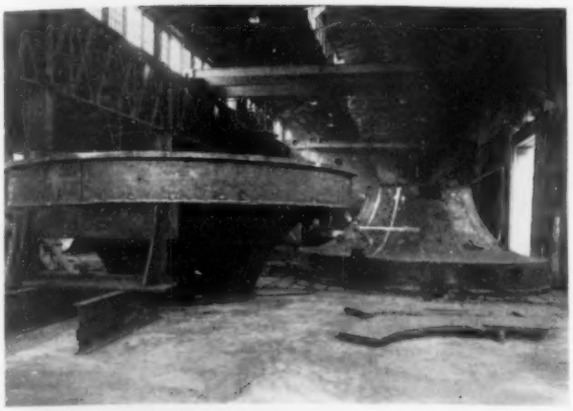
Although there had been a very substantial background of experience, it was realized because of the very large size and stresses involved that very careful study including consultation with expert welding engineers and welders would be essential. It was also necessary to purchase much additional equipment such as welding machines, cutting tools, tilting tables and to specially equip part of the works, including the installing of large machine finished floor plates. Further, it was necessary to increase the supervising personnel and to train a number of welders, for which purpose a school was established.

One of the incidental but important advantages secured by using welded construction for the speed ring and top plate, or covering members, was that an exactly homologous testing model could be made. By using a ratio of 4 to 1, the model, Fig. 14, was of reasonable size and expense and the plates were of exactly the same material, welded in the same manner and of the right proportional thickness. The tests on this model were of great importance because the design of the equipment and the work it has to perform are such that many of its constituent members cannot be exactly analyzed for stresses. From field tests on similar installations, it was known with accuracy what the loading would be and an analysis showed that a test model could be constructed and loaded in such a way as to produce stresses which would be closely comparable to those imposed on the parts under actual field service. The stresses in the model were determined by means of a battery of strain gages. Deflections were measured at many points as turbine parts must be designed not only for strength but for rigidity.

The information obtained from the tests proved to be of great value in designing these turbines and is applicable to the designs for similar units.

For the welded structures approximately 776 tons of rolled steel plate varying from $^3/_4$ in. to $3^1/_2$ in. were used. There was involved about 16,000 linear feet of

Fig. 9—Inner Top Plate



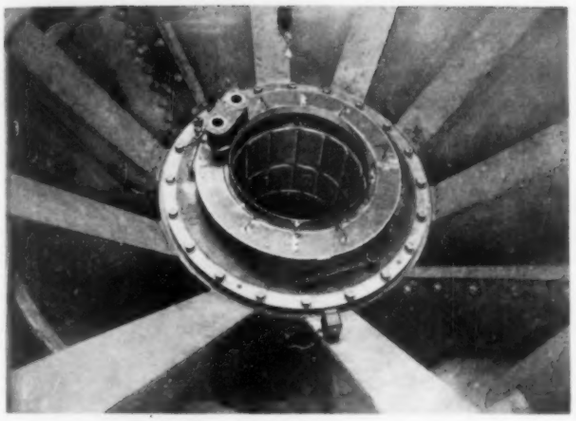


Fig. 10—Inner Top Plate with Main Bearing—"Craneman's View"

machine gas cutting, 24,000 linear feet of welding and 29 tons of welding electrode.

All of the welding was done with the work in the horizontal position. Many of the joints to be welded were very large in size so that there was a great deal of metal to be placed and positioning was necessary both for economy and assurance of quality. All the parts were stress-relieved excepting the pit liner which is subject to very little stress.

The expected advantages of the welded construction were fully realized. There was no trouble on account of distortion and the metal to be removed by machining was remarkably uniform in depth. Time and costs were within close limits of the estimates. No cracks or defects developed in the welds or in the other parts of the structures either before or after stress-relieving.

For a different type of turbine, but one in at least as frequent use, one of the best examples of the value of composite welded construction is the Francis turbine runner illustrated by Figs. 15 and 16. Here the hub, or crown, and the band are made of prefinished steel castings and the buckets are hot formed plates welded thereto. Before welding was available, this type of runner was most frequently made in one solid casting, using cores for all of the mold excepting the crown or hub structure. A large percentage for low heads were made by using hot formed plates cast into a cast-iron crown and band or occasionally into cast steel. The plates were perforated by punching so that the cast metal would flow through and assist in holding them in place.

The advantages of the composite welded construction are many. Hydraulically an important improvement is secured because the water surfaces of the crown and band are made smooth and to exact size and shape by prefinishing. The buckets can be set-up and held more accurately in position and the crown and band can be exactly centered. There results a runner more perfectly balanced hydraulically and mechanically.

The use of plate material for the buckets has the advantage of being able to obtain sufficient strength with thinner material than with the cast buckets, thus providing a larger cross-sectional area for the passage of water and increasing by a substantial percentage the power from a runner of a given size. This advantage was obtained also by the cast-in plate buckets, but this is a difficult casting to make perfectly. If the molten metal is not hot enough, the buckets do not thoroughly knit with the crown and band and if the metal is too hot or if in proportionately too great volume, the plate material will be burnt and lose its strength.

The composite welded runner is superior to either of the other types in every respect. Experience has shown that it is not cheaper, but on the contrary more expensive by a substantial percentage. The product is enough better, however, to more than compensate for the increased cost. The runner, being the power producing member of the turbine, is its most important part but is responsible for only a small percentage of the total cost. The increased charges required for a welded runner over one made by another method is, therefore, on a comparative basis, a small matter. All runners are thoroughly stress-relieved.

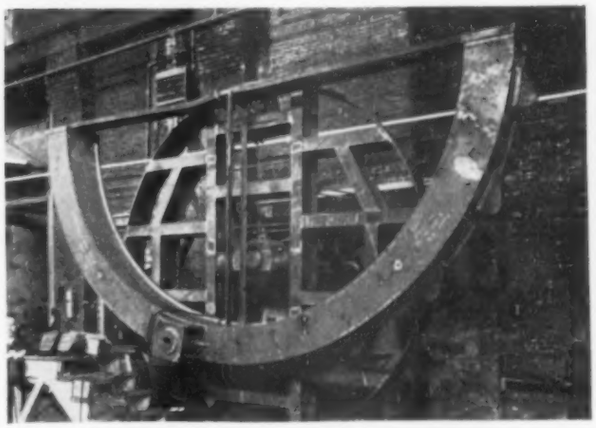


Fig. 11—Gate Shifting Ring on Horizontal Positioning Machine

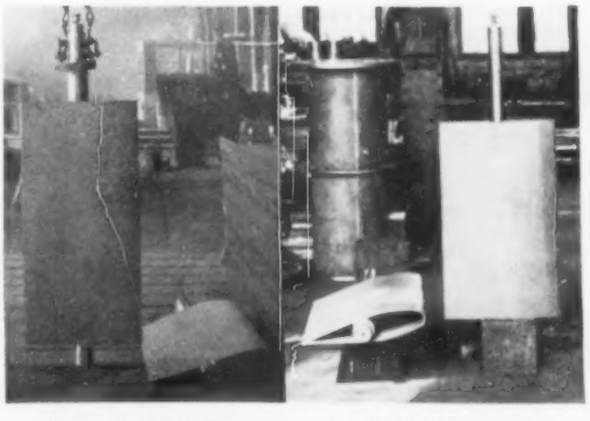


Fig. 12—Cast Wicket Gate

Fig. 13—Welded Wicket Gate

There are many welded runners in successful service, some for eight years. The demand is rapidly increasing showing a strong preference on the part of hydraulic turbine operators.

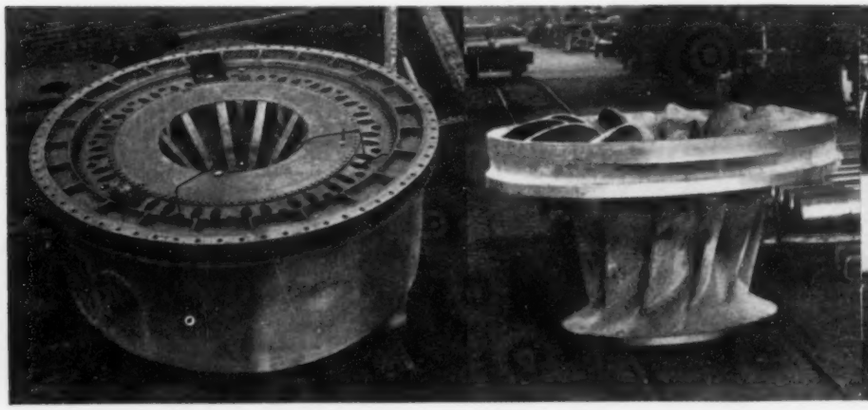


Fig. 14—Test Model for Turbine Cover Structure

Fig. 15—Welded Francis Type Runner—Side View

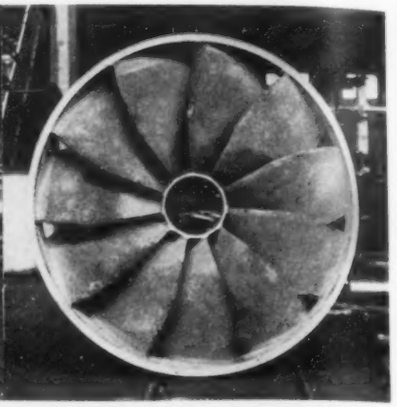
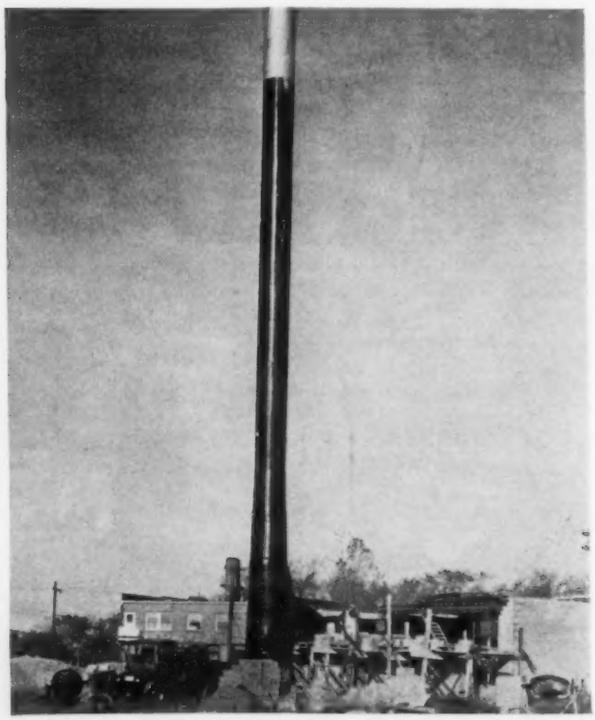


Fig. 16—Welded Francis Type Runner—View Looking at Discharge End

90-Foot Arc-Welded Stack Self Supporting

By P. C. SOWERSKY†

THIS self-supporting steel smokestack was built by electric arc welding by the Ohio Machine and Boiler Company of Cleveland for the Hillside Dairy, Cleveland. This 90-foot stack, the largest self-supporting structure of its kind in Ohio, is made of $^5/_{16}$-inch steel plate for the bottom 30 feet, and $^1/_4$-inch plate for the remainder.



† News Bureau, General Electric Company.

In such jointless stacks longer life is obtained as there is no opportunity for sulphuric gases given off by the furnace to collect, condense and cause deterioration between joints.

A Device to Aid Welding of Long Monel Sheets

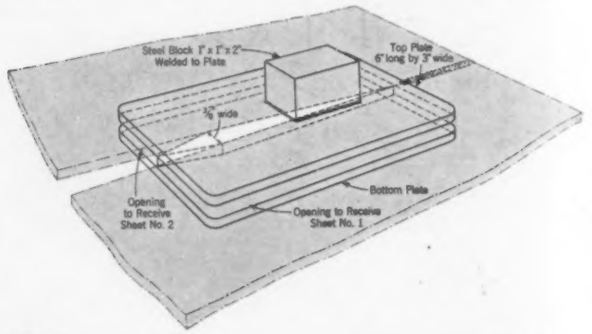
By W. F. SITLER†

THE novel device shown in the diagram comes from a welding engineer having long experience in the handling of monel and other nickel alloys. Its use, however, need not be restricted to these metals and probably will be found useful in handling long sheets of many materials in thicknesses between $^1/_{16}$ and $^3/_{16}$ of an inch.

As indicated, it consists of a steel wedge with steel plates welded on both top and bottom. It serves two purposes. First, it allows the contraction of the welded metal to pull the sheets together at a predetermined rate of speed, keeping the proper space in the seams at the point of welding. It also prevents sheets overlapping.

Secondly, the device keeps the sheets in line and one cannot pull above the other because of buckling from the applied heat.

A block of steel 1 in. by 1 in. by 2 in., welded on the top plate, is used to drive the wedge along the seam.



† Development & Research Department, The International Nickel Co., Inc.

Rail Welding*

By J. G. HARTLEY†

THE art of oxyacetylene rail end welding, as applied to railroad maintenance of way rehabilitation, has progressed greatly during the last four years.

The previously recognized equipment consisted of the following:

One welding torch 45-degree head, single flame tip.
One mixing head for above welding torch.
One welding tip, generally commercial No. 10.
One oxygen regulator—400/3000 gage.
One acetylene regulator—50/400 gage.
One adapter for acetylene cylinders, to accommodate different type threads on the acetylene tanks.
One four-way wrench, to accommodate all size nuts used on the equipment.
One pair welder's goggles—shade 5 or 6.
50 feet of 1/4 in. hose for oxygen.
50 feet of 1/4 in. hose for acetylene.
One pair of welding gloves.

With the above outfit the railroad began to experiment in the building up of adjacent rail ends, where one end was lower than the other, due to service wear; also to the original mill rolling. It is a well-demonstrated fact that as the rolls, for rolling rail, wear a different size in the rail results, which has to be taken care of even if rails from new rolls are placed in service against rails rolled from worn rolls. Chipped rail ends were also rehabilitated.

The building up or welding was at first limited to yard tracks and light traffic sidings, owing to the fact that the welding of rail ends was a new departure in maintenance of way methods and no one could definitely state that it would be successful.

The lack of new material and the necessity of maintaining increased traffic at reduced unit costs led some adventurous individuals to remove some of the restrictions on this method of rehabilitating the track structure by authorizing its use on Branch Line main track, having a preponderance of freight traffic.

Freight traffic lines then used so-called "fit" rail removed from main line high-speed tracks, which resulted in rails being laid in Branch Line main tracks of vastly different heights and head cross section, even though the rails themselves might be all of the same type and rail section, due to the length of service, density of traffic and physical characteristics of the district from which removed.

Prompt attention had to be given this condition, to avoid damage to heavy loaded freight equipment and wrecks which might follow:

Building up of battered rail ends followed vigorously; maintenance conditions were vastly improved until under the then existing traffic; pieces of welded metal applied peeled from the rail head, and rail ends began to break in the joints which necessitated a prompt investigation as to the cause of the peeling off of the welded metal, as well as the rail breakage.

It was the general practice in the building up of rail ends to attempt to reform the rail head to as near the original rail head contour as possible, commensurate with the amount of metal over-run existing on the rail head being welded, and also to reopen the space between the rail head ends by driving what is called a hot chisel between these ends.

In reforming the rail head, cracks and laminations are produced in the head due to working the metal too cold, which results, under rolling wheel loads, in portions of the rail head splitting off or the rail fracturing.

Metal cannot be reformed except when brought to the proper heat uniformly through the portion to be reformed.

As it is impossible to uniformly heat the entire portion of the rail head surface, which is influenced by the above-mentioned reforming method with the oxyacetylene torch, no reforming of rail head metal should be attempted or the hot chisel used to separate rail ends after building up the rail ends by welding so as to eliminate any possibility of creating incipient cracks or laminations, which might ultimately result in a fracture of the rail, resulting possibly in a train accident.

In the use of the single flame welding torch, the time consumed in bringing the rail head surface to a welding heat, over a small area, as compared to the entire rail head surface area, to be built up requires a certain period of time. Additional time periods are required to deposit the weld metal over this same small area. Three to four similar applications at least of the welding torch heat is required to cover the entire width of the rail head surface for only a short distance from the rail end, possibly one inch in length or less. If the weld is to cover four inches from the rail end, twelve to sixteen heavy applications of the welding torch heat is required to just apply the weld metal where required.

Each application of the welding torch heat, as above described, overlaps the rail head surface area previously heated and welded, which results in driving the original heat zone of the first application farther into the head of the rail toward the junction of the head and web.

In order to smooth the applied or welded metal, the rail head surface area must be again heated to just below a welding heat, which drives down still farther the heat penetration resulting from the weld.

As any manual welding operation is influenced to a large degree by the personal equation of the welding operator, the results obtained vary greatly according to the operator's welding skill and his inherent stability. An unsteady hand, combined with wavering eye, produces anything but a uniform weld.

The heat penetration of the rail head, in any welding method, is of paramount importance, for if the heat penetration is permitted to reach or go below the junction of the head and web, due to the decided difference in cross-sectional area between the rail head and web, stresses are set-up by the atmospheric cooling after welding, which after, as found by past experience, causes incipient cracks resulting in possible rail failures.

* Presented at January 18th Meeting, Philadelphia Section AMERICAN WELDING SOCIETY.

† The Pennsylvania Railroad.

The necessity of maintaining the surface of adjacent rail ends in the splice bar of the same height cannot be disputed if good riding qualities of rolling equipment, with low repair costs, as well as less rail wear due to rolling wheel batter, and less roadway maintenance costs are desired.

The use of a single flame welding torch is satisfactory for the building up of switch points for yard and unimportant siding use when the work is properly done; but, due to the possible extreme heat penetration required before the work is completed on battered rail ends, it was necessary to find a means to lessen the actual welding time; also the peening time so as not to work the deposited metal under a cherry red heat.

To accomplish this a two-flame welding tip was developed, consisting of two No. 10 welding tips side by side, brazed into a gas distributing chamber. The gas end or inlet of which was attached by a threaded end to the gas mixing head of the welding torch.

The two actual welding tips would be spread at the bend and fastened firmly by a split brass spreader, which fits snugly to the diameter of each tip and maintains the distance, center to center, between the tips above the bends, and the welding tip orifices be positioned $^5/_8$ in. center to center, so as to allow each welding tip to consume its proper portion of atmospheric oxygen, as by placing two welding tip orifices close together, the full individual heat of each tip is not obtainable.

The welding tips, from orifice to bend, are aligned to converge at the orifice in order to deliver the torch heat at right angles to the rail head surface contour, thereby securing, by the spacing and alignment of the welding tips, the maximum heat from the torch and eliminate the waste heat which ordinarily is deflected from the rail head surface, utilize freely the atmospheric oxygen and not having one flame interfere with the other.

The two-flame tip operation covers practically twice the surface of a single or one flame tip and a round welding rod cannot efficiently be worked with it, as the time required to melt the $^1/_4$ in. round rod is considerably greater than when a flat $^1/_{16}$ in. x $^3/_4$ in. rod is used; consequently deeper heat penetration results, which is what should be avoided if we desire to obtain results near or equal to electric arc welding of rail ends.

In fact, the use of a two-flame welding tip in the building up of battered rail ends consumes half the time, at least, required to make the same weld with a single flame welding tip; therefore, the heat penetration of the rail head is at least half of that with the single flame tip.

The former practice of heating the deposited metal and using the flatter to bring the deposited metal to the desired rail head surface contour and to cross-cut the joint, or adjacent rail ends, with a hot chisel increases the heat penetration as previously stated; therefore, the deposited metal should be roughly leveled with a five-pound ball peen hammer by the welder while the deposited metal is not under a dull cherry red heat, or properly workable, and the welding, after cooling, should be ground to the rail head surface contour desired so as to prevent all unnecessary heat penetration and secure a good smooth rail head surface.

The flat or ribbon form welding rod, $^1/_8$ in. thick by $^3/_4$ in. in width by 36 in. long, was obtained and worked on the flat or $^3/_4$ in. side allowing the broader welding flame of the two-flame tip to readily bring the parent rail head surface metal to a welding heat, also fusing the broad, thin welding rod quickly with the surface of the parent metal reducing the time of the entire operation one-half, using the flatter to bring the weld to the surface required and the hot chisel to cross cut the joint or rail ends.

The results obtained, while a decided improvement over the single flame tip operation, did not—considering the variable personal equation of each welder—restrict the heat penetration of the rail head sufficiently; the depth of the heat penetration depending entirely on the ability of the welder to manipulate the welding torch at a fixed distance from the rail head surface, in order to apply the maximum heat from the torch at a constant, even rate which is most desirable, applying just enough heat to make the weld required and allow for the use of the flatter and hot chisel without driving the heat too far into the rail head.

In order to secure even heat penetration and fusion with resultant homogeneous metal, at the same time lessen the depth of heat penetration, it is necessary to speed up the actual welding operation; therefore, the three-flame welding tip was produced, each welding tip arranged so as to be in an extended radial line of the curvature of the rail head surface and a spacer at the top of the bend holding each tip to the predetermined spacing. The face of each tip orifice is set to the curve of the rail head surface, delivering a practically uniform heat across the entire rail head width to be welded.

The centers of the flame, from the welding tips, contact the curved surface of the rail head perpendicular to the tangent of the rail head curve at the point of application, with the result that the greatest amount of heat is applied and very little lost by refraction into the atmosphere from being deflected by striking at an angle to the rail head surface.

To insure even application of the heat, the entire welding torch is mounted rigidly on a welding torch carriage.

The welding torch carriage is mounted on a roller at each end. This roller has a concaved surface of 24 in. radius, which approximates the contour of the wheel tread worn surface of the rail head and allows the carriage with the torch to be manipulated by the hand back and forth, as required, longitudinally over the rail head surface.

At the back of the carriage is a double knurled adjusting screw, which permits the raising or lowering of the bracket to which is rigidly fastened the back or gas inlet end of the welding torch handle. The front end of the welding torch handle is rigidly fixed to a bracket, which fastened to the carriage front upright has sufficient looseness to allow a turning movement when the back of the torch is raised or lowered by the adjusting screw.

At the bottom of the welding carriage are two rollers, at each end: one on each side of the carriage, held in adjustable brackets, on one side, attached to the rigid braces of the carriage, on the other side, attached to a swing apron, held in place rigidly and operated by a thumb projection against a spring.

The small side rollers can be and are set so that the centers of the two main carriage rollers are directly over the center of the rail head, and the carriage is held on the rail head surface rigidly by these small side rollers against the side of the rail head.

On the front of the welding torch carriage are two steel shields; the one curved, acting as a screen to deflect the heat projected by the torch backward away from the operator.

The second shield is straight, fits over the rail head and down over the side of the rail head, with sufficient clearance from the sides of the rail head to allow the welding tips to be swung sideways across the rail head surface to smooth the deposited metal, by a slight pressure of the thumb projection of the spring apron, which frees the small side roller from the side of the rail head, thus allowing the sidewise or cross-the-rail-head motion of the welding tips.

The deflecting screen can be provided for either a right or left hand operator.

By the use of a welding torch, fastened rigidly to a welding carriage in this manner, whereby the position of the welding flame is maintained at the correct and therefore most efficient distance from the surface of the rail head, and by the setting of the welding tips over extended radial lines of the rail head surface curvature, the orifices so spaced, center to center, that each flame only slightly overlaps the adjacent flame, an even heat is thrown entirely across the rail head surface desired to be welded.

By the use of the above-mentioned equipment the welding time is again reduced one-half over the use of the two-flame tip; a light depth of heat penetration is obtained; the fusion is even, and a homogeneous metal deposit is secured throughout the welded area.

It is necessary, however, to use a welding torch having a larger gas flow, and to use three cylinders of acetylene to one of oxygen, in order to conform to the required working pressure limit of acetylene gas (15 pounds), actually using a working pressure of from 13 to 14 pounds.

The three acetylene cylinders are connected together by manifolds containing a flash-back arrester.

The equipment used for the three-flame tip operation is as follows:

One Welding Torch.
One mixing head, No. 12-15.
One three-flame No. 10 welding tip with tip spacer.
One oxygen regulator, 50/3000 gage.
One acetylene regulator, 30/400 gage.
One three-cylinder manifold, complete with flash-back arrester.
One four-way wrench.
Three acetylene tank keys.
50 feet, 3/8 in. hose, two braid, red for acetylene.
50 feet, 3/8 in hose, two braid, green for oxygen.
One gas welding torch carriage.
One oxygen and acetylene tank carriage, when desired.

The equipment used for the two-flame tip operation is as follows:

One Welding Torch.
One mixing head, No. 10-12.
One two-flame No. 10 welding tip with tip spacer.
One oxygen regulator, 50/3000 gage.
One acetylene regulator, 30/400 gage.
One two-cylinder manifold, complete with flash-back arrester.
One four-way wrench.
Two acetylene tank keys.
50 feet of 5/16 in. hose, two braid, red for acetylene.
50 feet of 5/16 in. hose, two braid, green for oxygen.

In order to secure greater production, with less moving of the gas tanks, we have used a 100-ft. section of 5/8-in. hose from the tanks, to which is attached the specified hose lengths above mentioned, which, in turn, is attached to the welding torch. The larger diameter hose acts as a reservoir to maintain the gas pressure desired at the welding torch.

The battered surface to be welded is generally on the rail head surface curve from its junction with the fillet curve connecting with the side of the rail head.

By the use of a flat welding rod, 1/16 in. thick by 1 5/8 in. wide by 36 in. long, the rail head surface to be welded, after being brought to a welding heat, is quickly supplied with metal over the entire width of the rail head surface to be welded, and the welding torch is operated slowly backward and forward across and longitudinally over the rail head surface wherever the deposit of metal is necessary to bring the rail head to the surface desired.

The welding operation is performed quickly, and there remains sufficient heat for the welder to hammer the weld metal to an approximate flat surface, thus hardening the welded surface; also with the absolute precision of the heat application, an even, light heat penetration and even fusion are obtained, making a homogeneous deposit with the parent metal without any danger of unequal cooling of the rail structure, as only the surface of the rail head (which is what is desired) is brought to a welding heat.

However, the applied metal must be puddled with the parent metal to insure proper fusion. No brazing of metal to the rail head surface, to eliminate batter, should be permitted.

The deposited metal on each rail end should be hammered or peened as soon as sufficient metal is deposited on each rail end and while the deposited metal is not below a cherry red heat. No reheating of the applied metal for peening is necessary, as the deposit is similar in general character to the metal deposited on rail head surfaces by the electric arc. Therefore no additional heat should be applied to the deposited metal for the purpose of further peening to provide a smoother surface, but such surface should be secured by grinding, thus lessening the possible depth of heat penetration.

The welded portion is then ground to a true surface and the rail ends cross cut with a 1/8 in. width by 8 in. diameter abrasive cutting wheel operating at 9500 surface feet per minute.

Battered rail ends, to be properly reconditioned to withstand the hammer blows of rolling axle loads at the increased speeds demanded, must be ground to a smooth surface, which becomes an integral part of the adjacent rail head surface gradient.

The use of the hot chisel to provide a separation between adjacent rail ends, when so used, frequently (if not in the majority of instances) when the deposited metal is below a cherry red, causes laminations and incipient cracks to develop under traffic, resulting in chipped rail end head surfaces. These, in turn, add to the conditions causing rail end batter.

The precision results desired can be obtained only by grinding the deposited metal to a true surface and by cross cutting the rail ends with a 1/8 in. width abrasive cutting wheel, as previously described.

The use of the three-flame tip and welding torch carriage provides an all-year around method of reconditioning rail ends. Even with the grinding operation, which gives the true surface required, the per joint, per lineal inch and per square inch, costs are low with practically no capital investment.

However, as the building up of battered rail ends requires a certain expenditure, there should be obtained from this expense all the benefit possible and to secure this the following procedure should invariably precede the building up of any battered rail ends.

Track Conditions to Be Taken Care of Before Any Welding Is Done

Joints must be thoroughly tamped and brought to a true surface. Bars must fit snugly throughout, particularly at the center of the top of the bar, with sufficient drawing space between inside of bar and web of rail. If inside of bar engages web of rail, or is too close to allow proper drawing space, or does not have a close fit at the center of the top of the bar, bars must be renewed with reformed oversized bars

Bolts must be tightened, and, if necessary to secure proper tightness, must be renewed.

The proper expansion of rails at joints must be provided for and maintained to avoid chipping of rail ends when tight under traffic.

Joint ties must be renewed when necessary to provide proper joint support.

Ballast at joints must be clean to provide proper drainage.

Conditions to Be Taken Care of Before Any Welding Is Done in Building Up Open-Hearth Bolted Rigid and Spring Rail Frogs

All bolts, rivets and filler blocks should have original tight fit and, if and when necessary, should be renewed to secure such original tight fit. When frogs are badly worn care should be exercised, when tightening bolts and rivets, to see that the proper standard gage is maintained. Frogs should be in good surface and line, on good timber, and proper drainage conditions provided by M.W. & S. forces before any welding or building up is permitted.

Opening Between Rail Ends at Joints

To avoid chipping of rail ends at joints, all welded or rail metal over-run should be ground off flush with the original rail end.

Hot cutter should not be used, as their use increases the heat penetration of the rail beyond what is desired.

Deposit of Metal

In depositing metal on the rail head begin at the end of the rail and continue toward the end of the portion to be welded until the portion of the rail head to be welded is completed.

Heat Penetration

In building up rail ends with the oxyacetylene gas torch the heat should not be allowed to penetrate more than one-half the depth of rail head.

Other practices, which are generally accepted, are as follows:

General

All metal to be welded must be clean, free from dust, dirt, grease, paint or other foreign substance.

Where laminations, oxidized metal or cracks exist under the rail head surface, which cannot be thoroughly removed by the use of the wire brush or chisel, the bad material must be washed out with the torch before additional metal is applied.

All chipped or spalled rail ends shall be cut or washed down to clean parent metal, welded and brought to a true surface.

Rail ends which are cupped and the surface upset should have the cupped surface built up and the upset portion brought to a true surface.

When rail ends are not battered, but, when measured, show a difference in height, the low rail should be built up to the height of the high rail with the proper run-off or the high rail ground down to the proper surface with the low rail, if more economical.

All rail ends over-run by traffic and welded metal over-run should be ground off flush with the original rail end, and when rail ends are tight, they should be cross cut by a $^1/_8$ in. width cutting wheel to a depth of $^3/_{16}$ in.

Reforming or upsetting of rail head metal at joints in connection with gas welding should be prohibited.

To eliminate batter or any malformation of rail head at joints, metal should be deposited to build up the existing low portions and the joints brought to a true surface.

New Transport Plane Employs Arc Welded Construction

By MERRITT L. SMITH†

ONE of the first airplanes in which electric arc welding has been used to any great extent was completed recently by the Beech Aircraft Company, Wichita, Kansas. The plane known as Beechcraft Model 18 is an eight passenger transport with two 640 hp. radial engines and is capable of a cruising speed of 195 miles per hour.

Landing gear, motor mounts, wing braces and a number of fusilage members were fabricated by welding from S.A.E., X-4130 steel airplane tubing of 0.065 in. thickness and greater. Heavy coated electrodes were employed for all of the welding.

Before construction of the plane was started, considerable experimentation and development was necessary. Jigs and fixtures to permit positioning of work were devised. A welding technique was evolved calling for the use of mild steel electrodes in welding parts which were not to be heat-treated and for the employment of chrome-nickel electrodes on wing braces, motor mounts and other parts which were both preheated and post-heated.

All of the welded portions of the plane were tested under Department of Commerce supervision and proved to have a safety factor equal to or better than the required six plus. Test welds on heat-treated parts showed tensile strengths up to 140,000 lb. per square inch, and the completed landing gear assembly readily withstood a load test of 25 tons.

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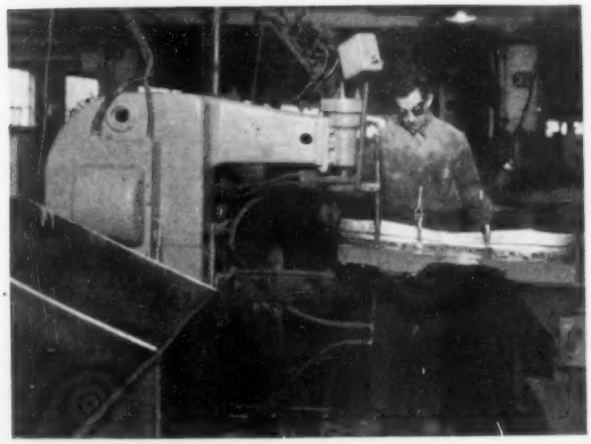
Welding Jigs and Fixtures

By JOSEPH W. MEADOWCROFT†

JIGS and fixtures used for welding are divided in different types due to the type of welding that is to be performed.

The most common used is the type to Electric Spot Weld (Resistance) which is of the portable type of jig that can be handled between the electrodes of a stationary upright electric welding machine. Jigs of this type must be light in weight due to the fact that they have to be handled by the operator plus the weight of material to be welded (Fig. 1). The aim in making this type of jig is to hold the weight of not more than fifteen lb. These jigs like all other jigs must have good gage points plus sufficient clamping device. There are times when the jig can be attached to the die holder of the welder to supply the gaging of an assembly which is to a big advantage due to the fact that the only handling that is done is the material to be assembled.

Fig. 1—Portable Jig



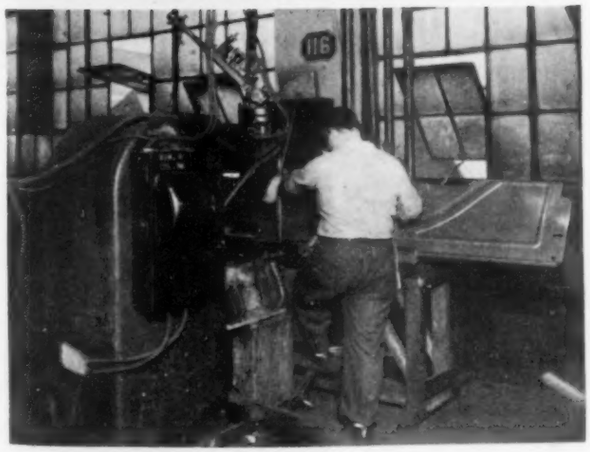


Fig. 2—Roller Conveyor Jig

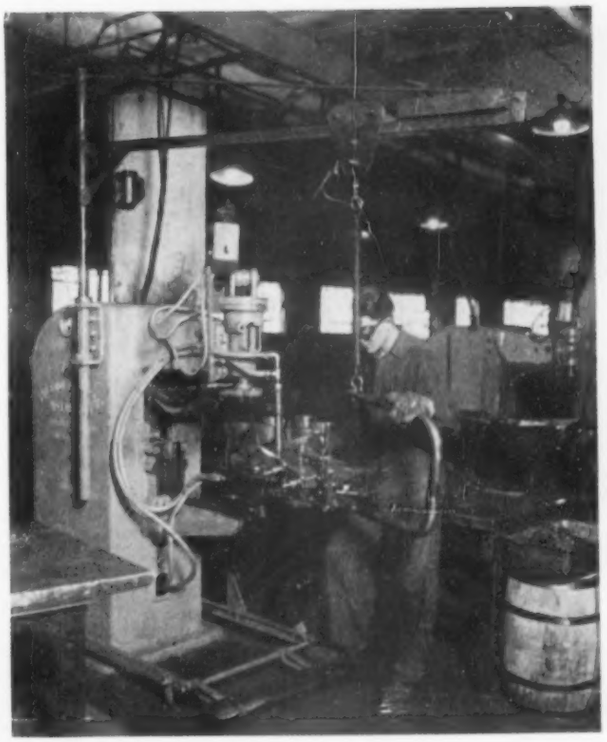


Fig. 3—Jib Crane Jig

There is a type of jigging that requires a roller conveyor in front of the stationary welder where the works can be supported and rolled under the machine with the least amount of handling. This is done where the material is heavy and the welding in a straight line (Fig. 2).

There is another type of jigging where the jig and work is suspended from a jib crane attached off the side of the electric welding machine. This is for material that becomes too heavy to handle and the weight of the material and jig is taken by the jib crane. Sometimes this is done with the use of a balancer where different height of welding is to be taken care of and the jig with the work in it can be brought under the dies of the welder with the least amount of effort (Fig. 3).

The stationary welder is put to another use in regard to the jigging of work, and that is when there is more than one spot to be welded at a time. This is done by use of projections on one of the members assembled (Fig. 4). This type is called Projection Welding. The jigging for this type of work is usually done by using the copper dies with gaging to position the work. As a rule these dies or jigs as you may call them have inserts at the points where the projections come of such material as tungsten copper or similar wearing material to take the wear as it is always at the same place. All gaging in this type of jig or die has to be insulated. These dies are put in standard holders of the machine and clamped in

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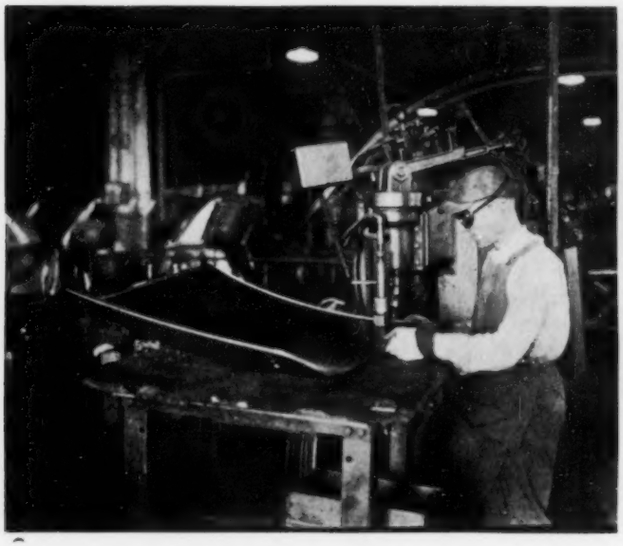


Fig. 4—Projection Welding

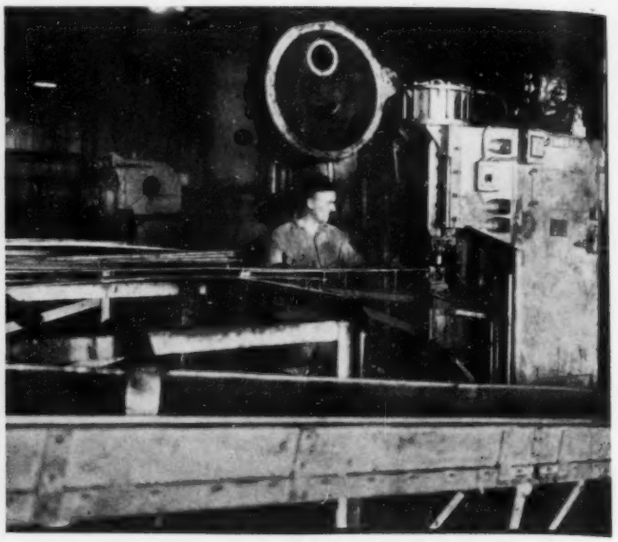


Fig. 5—Dies for Projection Welding

place (Fig. 5). There are stationary welders of this type, namely Press Welders, which are used when a large multiple of projections are to be welded over a fairly large area. This welder is built different and is of a heavier duty. The jig in this case is of a copper casting structure bolted to a base which the machine provides. Inserts as previously stated are used at the point of projections and in both cases these jigs are water cooled by either cast tubing or in the smaller ones by drilling and tapping holes and applying pipe nipples to same.

Leading from this to the work that is heavy or awkward to handle we get into portable welding instead of portable jigs, which in turn results in stationary set-up jigs. In jigs of this type weight is not the factor that has to be overcome, but the gaging and clamping are of the same importance of leaving space for clearance for the portable welder to perform the welding operation (Fig. 6).

The use of portable welding is far greater than just with stationary set-up jigs. Conveyor set-ups where the work is jigged on a conveyor frame or carrier, the portable welder being on a track overhead performing its work as the conveyor is moving (Fig.7). The type of jig made here is of a kind where there is not much gaging to be done and little clamping as most of the conveyor welding work is performed after work of a sizeable nature has been tack-welded in a set-up and placed on the conveyor for final welding. Conveyor set-ups are in some cases set-up and welded complete in which case the jigging has to be of a more accurate set-up as to gaging and clamping. These jigs are usually of a frame or structural make-up (Fig. 8). The favored set-up for welding on conveyor is the first type as a conveyor set-up comprising a multiple of frames, which if to be made and held exactly alike throughout a program, would involve quite a high maintenance inasmuch as each has to produce the same article with the same accuracy. Due to the fact that these do have to be alike it is well to number each conveyor frame so that we may detect any one and spot it if the product is not being produced uniformly.

Bar welding as it is called is another form of welding that is frequently used where the set-up is too large to handle under a stationary electric spot welder or too great a spot for a welder to reach. These jig set-ups are constructed with stationary copper as part of the jig under the surface that is to be welded and by the use of a bar welding tool, which is really the opposite terminal of the electric circuit set-up. The stationary copper is connected to one terminal of the transformer and the bar which has a cable connection to the other terminal of the transformer. In the design of such a jig there is constructed a member which is used to back up or heel the bar to get leverage on the bar because there is no other pressure set-up here for welding outside of the pull the operator exerts on the bar. This type of fixture and welding is never used where stationary or portable electric welding can be substituted.

Electric flash welding is a means of welding used where there are two surfaces to be butted together and welded without overlapping, as on all other previous methods the work was overlapped for each particular type of welding. The jigging of such work to be electric flash-welded always develops in a stationary set-up fixture. These fixtures are regular machines which locate the work and clamp the work with a jaw or gate construction which has an aluminum bronze die attached. Under this gate is a supporting structure which has an Aluminum Bronze die to which the gate clamps the work. These dies are water cooled. This machine is made in two halves, one-half clamping the one member to be welded,

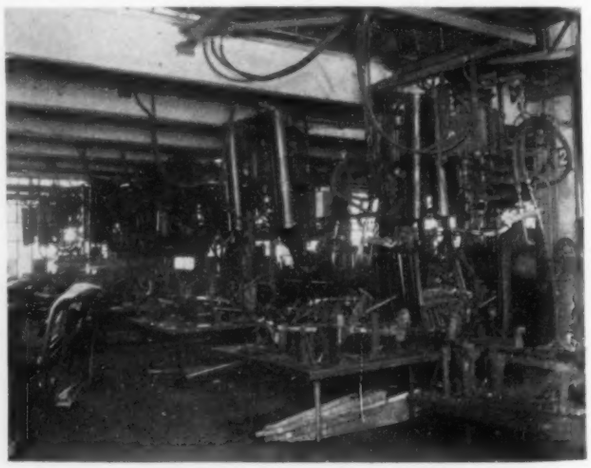


Fig. 6—Stationary Set-Up Jigs for Portable Welders

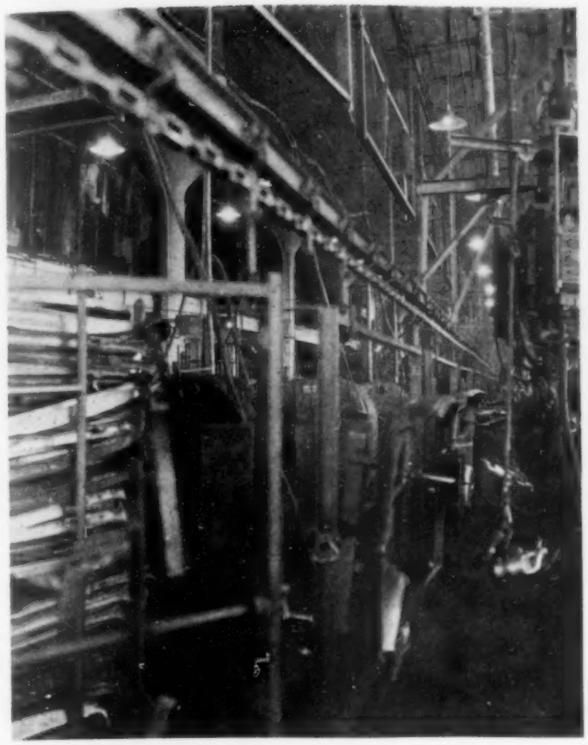


Fig. 7—Portable Welding with Conveyor Set-Up

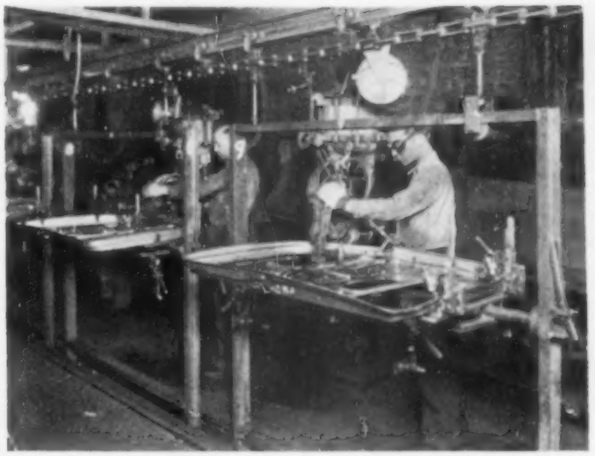


Fig. 8—Frame Jigs for Conveyor Set-Up

and the other half clamping the other member in similar manner. There is one-half stationary at all times, but the other half actuated by a motor drive, moves in to meet the stationary half, and when the electrical unit is put into operation the butting together of these parts develops the welding desired. A final push-up is actuated by a cam action on the motor shaft.

There is usually about $^{7}/_{32}$ in. to $^{1}/_{4}$ in. allowed to burn off each piece before welding depending on the thickness of metal and therefore these machine halves have to be set far enough apart so as not to touch before welding. There is great pressure put on these hold-down gates to keep the metal from slipping, usually actuated by the use of an air cylinder at both ends of the gate. Flash-welding jigs have to be designed and built to produce speed in handling and in a good many cases air clamps are used to position materials to be welded. Arc-welding jigs are used to position material usually of heavy gage which is to be arc welded. These jigs are no more than positioning jigs usually of heavy construction. In the design of arc-welding jigs there is always an opening or groove allowed at the point of arc welding for clearance of the welding tool and wire. Long seams of light gage metal sometimes are arc welded in jigs in preference to flash welding due to a low production. These jigs have all the clamping and gaging features of the flash-welder. The jig of arc welding is built in one stationary set-up, however, with the lower support at the point of arc welding of a bronze material, due to the fact that the material will not as readily stick to the jig. On arc welding seams of heavy gage metal we do not always need a backing as the rigidity of the material to be welded is not flexible, the heat is concentrated at the seam only. Water cooling is used at times in arc welding jigs usually where light gage material is to be welded but not as a rule on heavy gage welding of this type. Arc-welding jigs are no more than set-up jigs used to position a number of parts to be welded as in a built-up frame or corners of a unit that has to be welded. The one thing to keep in mind is to clamp the pieces securely as close to the point of welding as possible, leaving an opening to get in to weld.

Gas-welding jigs are built very much in the same manner of construction as the arc-welding jigs. The one exception in construction of gas-welding jigs that differs from arc welding is that the lower support of the jig at the seam or joint of welding must have an opening to allow the flame to go through. Gas welding more so than arc-welding jigs should be water cooled due to the fact that the heat is not as much concentrated and the jig is more likely to be heated more than in the arc welding operation. Welding jigs in general follow through with the same idea in mind of jigging that the foundation is good gaging, good clamping, and a good production jig where the results will be the best production of the best quality and uniformity with the least amount of handling involved.

Jigging is not required where a multiple of production is not needed. Where a multiple is needed, jigging is necessary to insure the sameness and interchangeability of the product.

Welding Cast-Iron Impeller in Chemical Plant

By W. M. LYON†

The welder at a chemical company plant tried to build up the iron impeller of a gas pump that had been used for pumping a mixture of chlorine and coke gases. These gases had corroded the casting, and the surface layers were filled with iron salts. Therefore, manganese bronze applied would not "tin" and stick to the cast iron. When the iron was machined, it was found to be very porous, and when the writer tried to apply the bronze he had the same trouble. Then he tried oxyacetylene welding with cast-iron rod and flux. By working the salts out of the iron as dirt or oxide was able to get a very good bond. The impeller was then machined and the deposited cast iron was found to be non-porous and well bonded in.

† Philadelphia Office, Air Reduction Sales Co.

Oxyacetylene Welding of Sheet Metals*

By C. G. BAINBRIDGE†

This Article Emphasizes All the Factors to Which Close Attention Must Be Paid if Strong Sound Welds of Good Appearance Are to Be Secured. As Well as Discussing Actual Welding Technique, It Points to the Benefits to Be Derived from the Use of Jigs in the Joining of Sheet Metals by the Oxyacetylene Process

THE successful application of oxyacetylene welding to the joining of sheet metals depends on careful attention to several factors. Placed under broad headings, these factors are: (1) Preparation of the welding edges; (2) correct welding procedure (flame, blowpipe technique, welding rod, etc.) and (3) location of weld, design of the welded article and the use of jigs or welding fixtures.

Types of Joints

The usual types of joints used in connection with the preparation of sheet metal edges for welding are shown in Fig. 1. Probably the most general type employed is the plain butt shown at *A*. In the thinner gages, if the edges are close butted, this type of joint can be made without the addition of welding wire, but the heavier gages need filling wire if reinforcement or build-up of the weld surface is desired, especially when the edges are slightly separated. With this type of joint, when the weld is made on one side, contraction of the weld metal upon cooling tends to depress the weld surface or raise the metal at the sides of the joint, as shown at *B;* in order to counteract this, the meeting edges are sometimes arranged as at *C*.

Unless jigs or clamping devices are used (to be dealt with later) the alignment of the two edges is maintained by tacks, spaced at regular intervals along the joint. For steel, tacks should be about 2 in. apart, about $1^1/_2$ in. to 2 in. apart for copper, brass monel metal, etc. and 1 in. to $1^1/_2$ in. apart for aluminium.

Welds in sheet steel can often be made without tacking the edges or without using welding wire. This can only be done when at least one of the edges is free and capable of being manipulated; the natural spring of the metal enables the welder to hold the free side with one hand while melting the edges together with the blowpipe held in the other hand. In the case of a butt joint in flat sheets, one side of the joint should be clamped to a stiffening bar (*D*, Fig. 1), or in the case of a corner joint the rigidity of one side is sufficient (*E*). The edges of the flat joint should meet at a slight angle as at *C*. In making the joint, the blowpipe is moved progressively forward, the contraction of the weld metal drawing the edges together; as the weld progresses a very slight sideways movement of the blowpipe is usually desirable. The duty of the hand holding the free edge is to guide the alignment of the two edges and control the rate at which they meet (Fig. 2). Such welds are usually made more rapidly than joints necessitating tacking and welding wire, and the joint is free from distortion after welding. Joints can often be prepared so that the metal for making the joint is derived from one or both of the edges to be joined.

The flanged edge type of joint shown at *F* (Fig. 1) can be used up to 16 gage; it is more suitable for non-ferrous metals than for steel. Unfortunately, the flanging is often carried out in a very haphazard way, which produces untidy, irregular welds. When the flanging is properly done the preparation is very effective, as it almost eliminates the necessity for welding wire and the flanges impart a little extra rigidity to the edges, which is very useful in maintaining alignment. The upturned edges are held together by tacks (spaced at longer intervals than for free butt edges) or pinch clamps. Similar types of joints utilizing metal from one or both of the edges as filling metal and not necessitating a regular addition of welding wire are shown at *G*, *H* and *I*. These joints are very largely used for attaching the

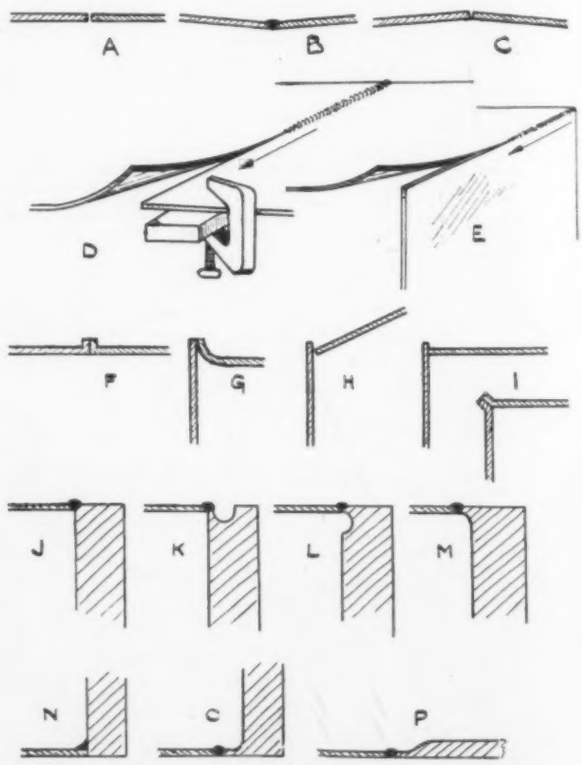


Fig. 1—Methods of Preparing Sheet Metal Edges for Welding by the Oxyacetylene Process

* Reprinted from February 1937 issue of *Sheet Metal Industries*.
† Sales Technical Service Dept., The British Oxygen Company Ltd.

ends to the shell of drums and cans. Although these joints very largely dispense with welding wire, it is always as well for the operator to be provided with some wire in order to compensate for irregularities of the preparation.

When a sheet metal edge is to be welded to a thicker or heavier portion of a structure or article the edge of the heavier portion should be reduced to approximately the same thickness as that of the sheet. Unsatisfactory types of joint are shown at *J* and *N*, while *K*, *L*, *M*, *O* and *P* offer some suggestions as to how the thicker part should be prepared so as to provide a thin welding edge. In welding together two unequal thicknesses there is always a tendency for the thinner part to melt first, often resulting in adhesion, and not fusion, with the thicker part; hence, the necessity for reducing the mass of the thicker part at the point where welding is to take place. Whatever the preparation, the blowpipe should always be directed more toward the thicker part, as heat will be conducted away from the thin edge more quickly than it will through the sheet which is of uniform thickness.

Blowpipe Technique

The blowpipe technique for sheet metals is known as "forward" or "leftward" welding—that is, the flame (if the blowpipe is held in the welder's right hand) is directed toward the unwelded joint and welding progresses from right to left. In recent years some new oxyacetylene welding techniques have been introduced, but these are generally applicable to much thicker material which hardly falls within the category of sheet metal; generally speaking, there is nothing better than the "forward" welding technique for sheet metal up to $^1/_8$ in. or $^3/_{16}$ in. thick.

Welds can be made in either the underhand or vertical position; for vertical welding the forward technique is still employed, the welding wire preceding the flame along the seam. When it is desirable to produce an equal welding bead on both sides of the seam, the "hole" method of welding should be employed. Flat butt welding edges as at *A*, Fig. 1, with a space equal to half the thickness of the sheet, are used; the blowpipe flame is maintained long enough over the edges to fuse both edges completely, forming a round hole. The metal melted from the edges runs to the underside of the flame, and bridges the space between the edges; welding wire is applied in front of the flame, the added metal also running round the flame, forming a built-up bead on both sides of the seam (Fig. 3). This method can be used for aluminium sheet with the joint in the vertical plane, for underhand or vertical joints in steel sheet, and underhand welds on stainless steel.

Complete fusion of the edges and penetration of weld metal is assured, and if both sides of the seam are to be smoothed and polished, there is no danger of lack of penetration causing cavities or cracks in the finished surface.

In all types of welding, blowpipe manipulation should be restricted to movement along the seam only. Transverse or sideways movements only tend to spread heat over an unnecessarily wide band of metal, and on low melting point metals increase the risk of sagging and collapse.

Blowpipe powers recommended for different thicknesses of various metals are given in Table I. High gas pressures should be avoided, and the nozzle diameters chosen for the blowpipe powers given should provide for a "soft" flame—i.e., a large diameter nozzle produces a short, broad, soft flame, while a small nozzle produces a thin, long, sharp-pointed flame, which is generally regarded as a hard, harsh or stiff flame. Owing to the cutting or penetrating effect, a hard flame is undesirable for welding any sheet metals, especally the non-ferrous ones.

As a general rule, the flow of gases to the nozzle may be so adjusted that the flame is "neutral," but slight variations of this adjustment give better results for some metals. For example, a flame adjusted to oxidizing conditions suppresses the volatilization of the zinc content when welding brass; these details are indicated in the table.

Welding Wire

Welding wire should, generally, be similar in composition to the metal being welded, and wire should

Fig. 2—Welding Longitudinal Seam in Sheet Steel Drum, without Welding Wire or Tacking

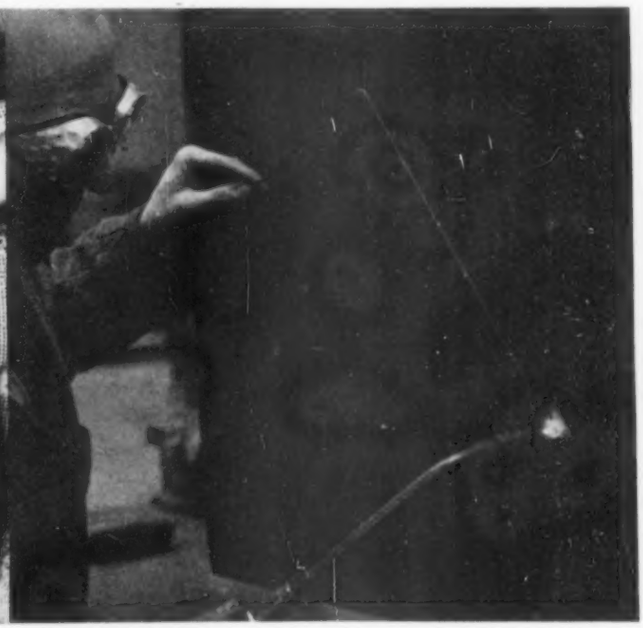


Fig. 3—Illustrating the "Hole" Method of Oxyacetylene Welding with Vertical Seam

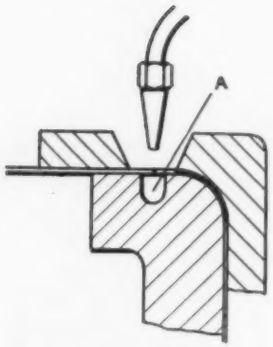


Fig. 4—Circumferential Seam

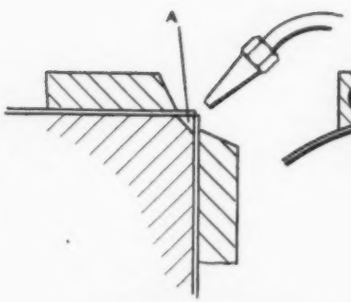


Fig. 5—Corner Seam

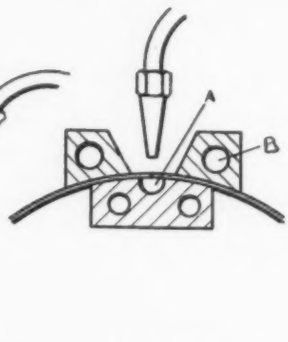


Fig. 6—Longitudinal Seam

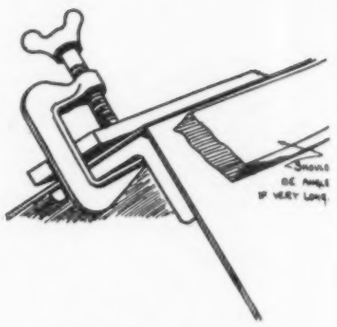


Fig. 7—Improvised Corner Jig

Figs. 4 to 7—Types of Jigs for Various Forms of Welded Joints in Sheet Metal

always be used in preference to strips cut from the sheet. The wire should never be less than $^1/_{16}$ in. diameter; in fact, for metals having a low melting-point, such as aluminium, the welder can exercise more control over the molten puddle by using a rod as large as $^1/_8$ in. diameter, for even 16-gage sheet. Although pure aluminium wire is generally employed for welding sheet aluminium, welders should bear in mind that there are on the market aluminium wires containing silicon and having a lower melting temperature than pure aluminium. Such rods are useful for joining very thin sheets or for making neat fillet welds as, for instance, between the spout and body of aluminium kettles or between thin and heavy sections.

Another point that is often overlooked by the welder is that a bronze rod can be quite often employed for joints in steel and copper. Such joints are not welds in the strict sense of the term, as there is only a surface bond between the bronze and the base metal. Tests have shown, however, that this bond is very good and will withstand the working stresses usually sustained by a joint. The value of the process lies in the fact that the bronze melts at a lower temperature than either steel or copper, and for steel especially it is very useful in joining very thin sheets to heavier sections, such as paneling to rigid frames. As there is little or no penetrative effect, it is not possible to clean off the weld metal flush with the sheet surface, otherwise the strength of the joint will be removed; but for any joint where the deposited metal can be left as welded the method is quite satisfactory. Owing to the low melting-point of the bronze (800 to 900° C.), bronze-welding should not be used on articles subjected to temperatures higher than 450° C., as above this temperature bronze loses its strength very rapidly. Bronze can be also used for making joints between dissimilar metals such as copper and steel, steel and cast iron, and copper and brass, but it is not suitable for use with aluminium.

Fluxes for Oxyacetylene Welding

Owing to the fact that all metals tend to oxidize when heated or melted and that the oxide of most non-ferrous metals melts at a higher temperature than the metal itself, a flux is necessary for non-ferrous metals in order to prevent oxide being trapped in the solidified weld metal. Oxide of iron or steel melts at a lower temperature than the metal and is dissolved in the weld puddle, so that a flux is not necessary.

All fluxes should be used sparingly, partly because of the trouble of cleaning-off burnt flux after welding and partly because of the risk of including particles of flux in the weld metal. Aluminium flux especially is corrosive, and flux included in the solidified weld metal sets up internal corrosion of the weld which cannot be stopped afterward. It is therefore, very important to wash off all traces of aluminium flux from the front and back of aluminium welds, before the weld has cooled, with hot water or a weak solution of nitric acid, finishing washing with clean water.

The practice of applying flux by heating the end of the welding wire and dipping it into the flux is bad owing to the irregular, and usually excessive, amounts of flux that are supplied to the weld.

Table 1—Blowpipe Power for Various Sheet Metals

Sheet Thickness			Blowpipe Power in Terms of Liters of Acetylene[1] per Hour for Various Metals					
In.	Mm.	S.W.G.	Mild Steel	Stainless Steel	Copper	Aluminium	Brass	Monel, Inconel
$^1/_{32}$	...	28	50	35	75	25	50	30
$^3/_{64}$	1	18	75	60	100	50	75	70
$^1/_{16}$	$1^1/_2$	16	100	75	175	70	100	100
$^5/_{64}$	2	14	150	125	225	110	150	150
$^3/_{32}$	$2^1/_2$	13	200	175	300	150	200	200
$^1/_8$	3	10	250	225	350	200	250	250
Approx.: Acetylene per hour per mm. (liters)[2]			60–75	50–70	100–115	50–70	60–75	70–75
Type of flame[3]			Neutr'l	Neutr'l cone: just commencing to carbonize[4]	Neutr'l	*Very slightly* carbonizing or reducing	Definitely oxidizing	Slightly carbonizing or reducing

[1] The consumption of acetylene measured in either liters or cubic feet per hour is the accepted method of expressing the power of an oxyacetylene blowpipe, acetylene being the fuel gas providing the heat value of the flame. Consumption of oxygen is the same as that of acetylene.

[2] Rule applicable mainly above 1 mm.

[3] Adjust flame to neutral with suitable size nozzle to give blowpipe power required at appropriate gas pressures. Then, for reducing or carbonizing conditions, open acetylene valve slightly; for oxidizing conditions, close acetylene valve slightly, according to degree of adjustment required.

[4] An excess of acetylene is not indicated. All that is required is the slightest possible "haze" or "mist" of acetylene round the luminous cone, in order to make sure that the flame is not oxidizing.

With low melting-point metals, such as aluminium, with which sufficient flux can be applied with the welding rod only, a better way is to pick up a "tuft" of flux on the end of the heated welding rod and with the flame melt down the tuft so as to varnish the rod surface. In those cases where it is necessary to apply flux to welding edges as well as the rod—for example, stainless steel and monel metal—the flux should be mixed to a paste with alcohol or methylated spirit and painted on both edges and rod. Another method of applying liquid flux to the rod is to keep some of the liquid in a cylindrical container holding several welding rods. As a rod is withdrawn, sufficient flux adheres to the surface of the rod. Needless to say, only as much rod as is coated with flux should be used before recoating or using a fresh rod.

Properly manufactured fluxes are recommended in preference to "home-made" fluxes, as, apart from exercising the required action, they contain the necessary ingredients to ensure that the flux melts at the right temperature and is sufficiently fluid when molten to avoid being trapped in the weld.

Welds in sheet steel, aluminium and copper can be improved by light hammering or rolling after welding; steel and aluminium should be hammered cold, but copper should be hammered hot. Hammering improves the weld strength and can be used to eliminate any buckling or distortion that may have taken place around the weld. Only light hammer blows should, of course, be used, and the underside of the weld should be supported by an anvil plate or dolly.

As far as possible, the positions of welds should be arranged so that they are not subjected to bending in the course of the service performed by the welded article. For example, the joint between the bottom and sides of tanks or vessels subject to change of shape, by pressure or weight of contents, should be arranged so that the bottom is flanged and the joint made as shown in Fig. 4. Again, instead of forming box sections so that the joint is at one corner, the seam should be arranged in one of the sides. Incidentally, corner welds are also unsatisfactory because it is difficult to eliminate buckling if any has taken place during welding and after-treatment of the weld is impossible.

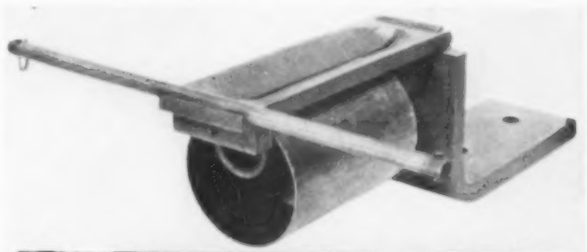
Use of Jigs

The benefit of properly designed jigs is fully realized by mass producers of welded sheet metal articles, but sheet metal workers do not always realize that jigs of simple construction and improvised clamps and "chills" are often possible for the "one's" and "two's." Sheet metals are not usually rigid or strong enough to resist the effects of expansion and contraction over the heat-affected areas surrounding the weld. Therefore, precautions should be taken to keep the metal adjacent to the weld as cool as possible, and to impart additional strength to the welding edges by means of rigid clamping pieces or jigs.

A jig will prevent waste welding flame from coming into contact with metal adjacent to the weld; it should also be massive enough to absorb or withdraw heat quickly from the weld, and be able to continue to do so for long working periods, without becoming uncomfortably hot for the operator. (Jigs for heavy sheet should be watercooled.) The jig should give adequate support to the sheet, as close to the weld as possible; the gap between the bottom edges of the V formed by the sides of the channel (between which the welding is done) need not be greater than $^5/_8$ in. wide.

In order to allow weld metal to penetrate to the underside of the weld, a channel or groove should be provided in the jig immediately under the weld, as at *A*, Figs. 4, 5 and 6. These illustrations show jigs suitable for circumferential, corner and longitudinal welds, respectively. Watercooling holes are indicated at *B* in Fig. 6. These are desirable for this type of jig, especially if the seam is long. A simple jig for a short longitudinal seam is shown in Fig. 8.

Fig. 8—Simple Jig for Short Longitudinal Seam Welds



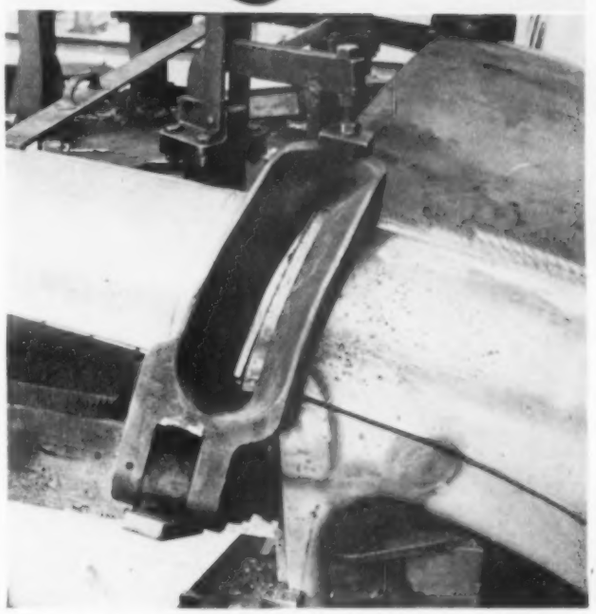


Fig. 9—Welding Jig for Seam on Curved Surfaces

These illustrations show the principle of the three main types of jig; they can often be improvised from ordinary bar, angle, joist or channel section steel, held together with screw clamps or wedges, but for the production of parts in any considerable quantity properly designed and machined, cast-iron jigs, with quick tightening and release devices, are well worth their cost. Such a jig is shown in Fig. 9.

An improvised jig, utilizing an angle section and two bars, and corresponding to Fig. 5, is shown in Fig. 7. For situations in which it is difficult for some reason or other to provide jigs, heat can be prevented from spreading to metal adjacent to the weld by surrounding the weld with pads of wet asbestos, cotton waste or clay; or portions of the structure may be immersed in, or sponged with, water during welding.

Welding of Chrome-Nickel Steel

A. S. M. E. Boiler Code Committee Case No. 834

Inquiry.—Will it be permissible to apply the Code symbol stamp to unfired pressure vessels fabricated by fusion welding of chrome-nickel steel conforming to A. S. T. M. Specifications A 167-35T, grade 4, with the following limitations:

Carbon, max., per cent	0.07
Manganese, per cent	0.40–1.50
Chromium, per cent	at least 17
Nickel, per cent	at least 9.5
Tensile strength, min., lb. per sq. in.	75,000
Yield point, min., lb. per sq. in.	35,000
Elongation in 2 in., min., per cent	30

It is pointed out that this class of material has previously been recognized in Case No. 792 and in the recently-issued Specifications S-33 for alloy steel castings, S-34 for seamless alloy steel pipe, and S-35 for alloy steel pipe flanges.

Reply.—It is the opinion of the Committee that stabilized austenitic chrome-nickel steel conforming to A. S. T. M. Specifications A 167-35T, grade 4, with the chemical limits modified as above, may be used for the construction of welded unfired pressure vessels, this steel to be stabilized with either columbium or titanium. The minimum columbium content shall be 10 times the actual carbon content with a maximum of 1 per cent; the minimum titanium content shall be 6 times the actual carbon content with a maximum of 0.60 per cent.

The rules in Par. U-68 shall apply, except modified as follows: The stress relieving and stabilizing heat-treatment of the vessel of columbium-bearing steel shall be performed at a temperature not less than 1550 F. and held at that temperature for a period of time proportioned on the basis of at least 1 hr. per inch of thickness but in no case less than 2 hr. and of the vessel of titanium-bearing steel shall be performed at a temperature not less than 1550 F and not to exceed 1650 F. and held at that temperature for a period of time proportioned on the basis of at least 1 hr. per inch of thickness but in no case less than 4 hr. The complete vessel shall be heat-treated as a unit, no local stress-relieving being permitted and it shall be allowed to cool slowly in a still atmosphere.

The welded test plates shall be made from the same lot of material as the vessel itself, they shall be heat-treated with the vessels, and, if possible, placed inside the vessel.

The free-bend test specimen, which need not be more than 6 in. in length, shall be subjected to a "susceptibility to embrittlement" test as follows: The specimen shall be reheated to and held at 1200 F. for 1 hr.; the top and bottom surfaces of the specimen shall be ground and polished and the specimen immersed in a boiling copper sulphate sulphuric acid solution for a minimum period of 48 hr. This solution shall consist of 47 cc. concentrated sulphuric acid and 13 grams of crystalline copper sulphate ($CuSO_4.5H_2O$) per liter of solution. After immersion the samples shall be bent as specified in Par. U-68. The elongation on the outside fibers shall not be less than 20 per cent, at which there shall be no evidence of fissuring.

Representative drillings of the weld metal shall be obtained from one of the welded test plates and the chemical analysis of the weld metal shall be within the following limits: The chromium and nickel content of the weld metal shall be within the same range as the parent metal; the columbium content of the weld metal, when columbium is used as the stabilizing element in the weld metal, shall be at least 9 times the carbon content of the weld metal and shall not exceed 1 per cent; the titanium content of the weld metal, when titanium is used as the stabilizing element of the weld metal, shall be at least 5 times the carbon content of the weld metal and shall not exceed 0.60 per cent. In case the chemical analysis of the first drillings of the weld metal fails to meet the foregoing specifications, two additional sets of drillings may be taken from the same welded test plate and the test shall be considered satisfactory if both these retest analyses meet the specifications.

The allowable stress in the design formula shall not exceed 15,000 lb. per sq. in., for operating temperatures up to 900 F., with a joint efficiency of 90 per cent.

"EDITOR'S NOTE. *The above interpretation by the Boiler Code Committee was adopted after a very thorough study and careful consideration of all factors entering into the fabrication and usage of the specified grades of austenitic chrome-nickel steel. The discussion disclosed the necessity for certain precautions to minimize the undesirable effects resulting from welded fabrication of certain types of this group of steels. The need for examination of corrosion resistant properties of the welded joints, particularly in the presence of fabrication stresses was emphasized. Data were presented as to the value of stabilizing elements. Reported experience with these steels indicated that it was necessary to clearly specify the heat-treatment and to limit the temperature of operation. Rules covering the welding of similar grades of unstabilized steels are under consideration. The A. S. M. E. Boiler Code Committee, 29 West 39th Street, New York, N. Y., invites the submission of information pertaining to experience in the fabrication of welding or usage of such materials.*"

Laboratory Corrosion Tests of Welded Low-Carbon Stainless Steel

By GEORGE A. ELLINGER* and LEON C. BIBBER†

WELDED specimens of low-carbon stainless steel (less then 0.06 per cent of carbon) were exposed to the corrosion attack of three different solutions. Results of these tests were as follows:

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†Senior Welding Engineer, Bureau of Construction and Repair, Navy Department.

In a copper sulphate-sulphuric acid solution, intergranular corrosion did not occur in either plate or weld metal regardless of the heat-treatment.

In boiling nitric acid, intergranular corrosion occurred only in certain heat-treated plates of low-carbon stainless steel. Intergranular corrosion did not occur in welded metal, with or without heat-treatment.

In hydrochloric acid of high concentration, the corrosion rate of plate metal was not affected by heat-treatment, but the corrosion rate of weld metal was considerably decreased by heat-treatment at high temperatures. Intergranular corrosion was not observed in any specimen exposed to this reagent.

These results can be explained on the basis of selective attack by the corrosive agents on certain constituents of the steel samples.

Welding on the Fort Peck Dam Project*

By WM. M. GALLOWAY†

THE first welding work undertaken in connection with the building of the Fort Peck Dam was on the Milk River Bridge of the Wiota-Fort Peck railroad.

In April of 1934 the engineers began to seriously consider the possibilities of welding. At that time it was proposed to lay a welded steel temporary water line through the area that was later to become the town of Fort Peck. The purpose of the system was to furnish water to the contractors and afford water for fire protection. Under the supervision of T. B. Jefferson, Assistant Plant Engineer, on April 16, 1934, a crew of five gas welders began welding on 22,000 feet of 6-in. and 8-in. steel pipe; and after three weeks of hard work the line was completed, tested and found to be leak free. During this same period the permanent gas line was being placed throughout the townsite by a private contractor.

When the water line was completed the welders were taken to the boatyard and used on various welding operations relative to the construction of the dredges and other floating plant to be used in this district. By this time the welding equipment of the district had been increased to eight gas-welding and cutting outfits and two arc-welding machines.

While the arc-welding machines were used for various miscellaneous welding jobs they were first put into regular service during the building of the water line to the tunnels and the spillway. The flanges on the 6-inch line used on the river crossing portion of this line were welded.

It was not until the winter of 1934–35 that welding really began to take its place in the district. The engineers of the Plant Section finally convinced the District Engineer that welding was the most practical method of reclaiming dredge equipment and as a result were permitted to establish a welding shop. Heretofore, the welding shop had been a part of the machine shop, but with the establishment of the welding shop as a separate unit of the engineer shops the welding activities began to increase immediately. At this time additional electric welding equipment was acquired and the personnel of the shop had increased to 35 welders and helpers. The major welding work of the winter months of '34 and '35 was there shaping of diaphragms of the dredge ladders to accommodate 33-inch suction pipe instead of the original 28-inch suction. Experimental welding of dredge pump casings and impellers was also carried on at the same time and proved quite successful.

In February 1935, Wm. C. Anderson became foreman of a shop that was shortly to become the largest hard-facing plant in the world. Special jigs and tools designed to handle 20-ton dredge pumps, 4-ton impellers and 9-ton cutters were soon put into service and production was stepped up. Thus, through the use of welding, thousands of dollars worth of dredging equipment was salvaged and reconditioned for further and more efficient service than obtainable from a new piece of equipment. The dredges were not the only items to receive the attentions of the welding crews for repair work was constantly being done on tractors, draglines, trucks and other items of plant. Likewise, the pipelines were continually being repaired and many new fittings fabricated. The most notable of these were special wyes, ells and valves. Many pieces of scrap were made into sand traps that proved to be better than those that had been purchased at several times the cost.

This is a rather sketchy outline of the work that has been carried on the past three years in the welding shop.—a shop that has grown from five welders in April 1934 to 150 employees now. At the present time 30 electric machines are in continuous use and with the aid of a few gas torches more than a 1000 pounds is being deposited daily.

The Engineers are not the only users of welding equipment on the job. There has not been a contractor on the project that has not employed advantageously in some manner the uses of welding. The largest users have been Frazier-Davis Company, the corewall contractor and Addison-Miller Co., the builders of the spillway gate structure.

While this paper is rather brief it has been the endeavor of the writer to point out some of the high lights of the welding work being carried on in this district. Many outstanding jobs have been undertaken and undoubtedly some of them have been overlooked in this presentation. When you consider that a book could easily be written of the welding on this project it is easy to understand how some of the more important accomplishments would naturally be omitted in this short paper.

* Presented at Jan. 6, 1937 Meeting, Montana Section AMERICAN WELDING SOCIETY.

† U. S. Engineers, Fort Peck.

Factors Affecting the Properties of Welds and the Base Metal Adjacent to the Weld*

By R. E. LONG†

THERE are many factors which do and will affect the weld metal and the parent stock. Of these the important ones are:

The technique of the welder.
Procedure set down for welding.
Condition of the plate before welding.
Analysis of the plate and rod used for fabrication.

* Presented at Feb. 19th meeting of Chicago Section, AMERICAN WELDING SOCIETY.

† Research Engineer, Hollup Corporation.

Of the above factors, it is the writer's belief that the ones which are of the greatest importance are those which affect the temperature. The effect of temperature has long been recognized in the making of forge welds, the driving of rivets, the rolling of plates, the hardening of tool steels and the proper heat-treatment of various steels to obtain desired physical properties.

Why then, should not these same precautions be taken in the joining together of two plates by the fusion method? Speaking theoretically, it should be possible to weld together any analyses of steel if the proper heat-treatment be given. This however, is not practical, and more or less impossible due to the sensitivity of the critical points or ranges of temperature of several analyses of steel.

In welding, the steels may be classified in three groups as to their effects after fusion. They are: (1) *Sorbitic* or *Pearlitic* have the faculty of combining strength, ductility and toughness. (2) *Austenitic* combines ductility and toughness and (3) *Martensitic* or *Troostitic* steels are hard and brittle.

Of these three it may be readily seen that the latter is where the difficulties in welding are most apt to occur. In welding these types of steels there is not much that the manufacturer of welding electrodes may offer that will weld without taking the necessary precaution of preheating so that the rate of chill will be retarded to the point which will cause no hard or brittle zone within the heat affected areas of the parent material.

If 100% joints be desired on these classes of steels, it is desirous to normalize at that temperature recommended for that analysis of steel. It is a good point to remember in welding that as the alloys increase the carbon should be allowed to decrease to avoid approaching the Martensitic condition in the steel. Nevertheless, carbon alone may cause this condition and a safe rule is to preheat all plate which has a carbon range above 0.35.

In the welding of the other two types of steel, very few difficulties are experienced in the hands of capable welders and supervisors. However, there are several precautions which should also be taken in the welding of these steels. When particularly heavy sections are being fabricated, it is recommended that slight preheating be done to allow no great thermal stress to be entrapped in the structure.

As for the remaining effects, such as the technique of the welder, procedure for welding, and the condition of the plate before welding, while they are very important, it is my belief that there are but few generalizations that could be advanced. This is said due to the fact that all fabricators have variations in their procedure which necessitate a decided difference in welding technique, set-up and preparation for welding, over a fabricator in a different line of endeavor. The best methods for the establishing of this is by the actual destruction of test specimens made under each particular procedure and individual technique. This should be done until ideal methods are established or reached. These facilities are available to the fabricators through the service engineers and laboratories of the various Welding Electrode Manufacturers.

There are some who say that these precautions are too great an expense to absorb, but it is the belief that after seeing figures on the cost of weld metal deposited which varied between $1000.00 and $2000.00 per ton, it can well be afforded in dealing with such an expensive material.

Welded Manifold

By A. F. DAVIS†

NOT a seven nosed mammoth unearthed from subterranean haunts, but the arc-welded inlet manifold to the Gene pumping station on the $236,000,000 Colorado River Metropolitan Water District Aqueduct, scheduled for completion in 1938. This giant arc-welded steel pipe (note size of men in photo) was fabricated by Consolidated Steel Corp., Los Angeles. A great deal of field work was necessary.

The capacity of the aqueduct—a billion gallons of water per day—will not be used immediately. Consequently only three of the outlets—those at the far end of the photo—will feed the pumps when the aqueduct is completed. Later, when future needs demand, pumps will be added to the other four outlets which for the time being will be closed by bull plugs.

† Vice-President, The Lincoln Electric Company.

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A summary of present knowledge on internal stresses (about 200 references). Effects of internal stresses (season cracking, etc.) methods of measurement, internal stresses in wrought materials, cooling, casting and hardening stresses. Only a few articles on shrinkage stresses in welds are discussed, and those very briefly.

A comprehensive book, entitled **"How to Weld 29 Metals,"** covering the procedure, conditions and materials for welding modern alloys has recently been published by the Westinghouse Electric and Manufacturing Company. Specific data for welding all types of joints with varying thicknesses of metal, such as electrode diameter, welding current, speeds, deposition, etc. are included. Prepared by Chas. H. Jennings, whose experience and exhaustive investigation into the joining of metals have eminently qualified him as an authority on the subject, this book should be of great value to welding operators in simplifying and improving the welding of present day metals and alloys. Copies of the book are available at 50 cents each, at AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y.

DETECTION *of* FATIGUE CRACKS *by* MAGNAFLUX METHOD

By T. C. RATHBONE

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DETECTION OF cracks and flaws in boiler drums and other pressure vessels by a process of magnetizing the object and applying a magnetic powder is being described in other papers that are printed elsewhere in this issue. The application of this method of inspection to ferrous objects in general, and in particular to the types of crack that develop in machinery parts as a result of dynamic forces may be of general interest.

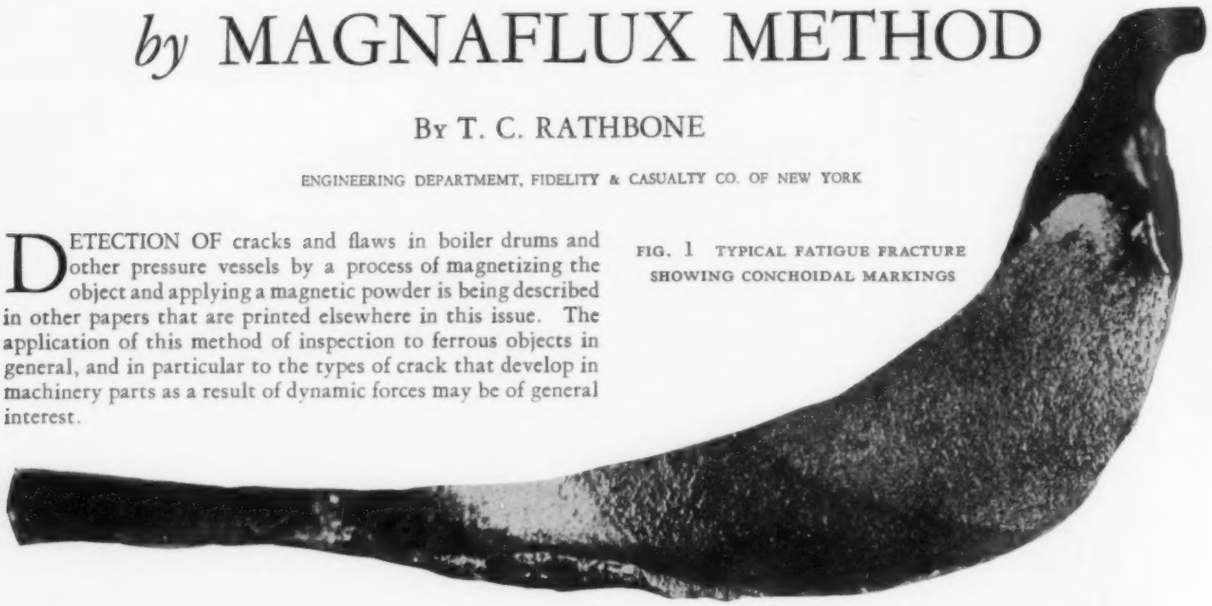


FIG. 1 TYPICAL FATIGUE FRACTURE SHOWING CONCHOIDAL MARKINGS

The chief characteristics of the true fatigue crack are its unexpected start and relatively slow progress, giving rise to the synonymous term "progressive fracture," and its invisibility, particularly in the early stages, which so often prevents detection. The degree of invisibility of fatigue cracks is often astonishing. Unless actual examples have been seen, it is difficult to believe that a well-developed crack can exist in a machine part under direct scrutiny without being visible, even with the aid of a magnifying glass.

Materials may fail at stresses considerably below the ultimate in direct tension, if the forces are applied in an intermittent or repeated reversal fashion. For a given material, a fairly definite relationship has been established between maximum fiber stress and the number of cycles of stress reversals required to start failure. From such data, the so-called endurance limit has been introduced in machine design, which is supposed to be the maximum allowable stress that can be applied with an infinite number of reversals without starting fracture. All machinery parts subjected to reciprocating forces from any cause are now designed in conformity with this principle. In spite of this, failures due to fatigue or progressive fracture are still being experienced to an alarming degree.

CAUSES OF EXCESSIVE STRESSES

These failures are fundamentally due to the existence of stresses beyond the endurance limit, in spite of the provisions in design to avoid this very condition. These excessive and unanticipated stresses leading to failure are almost always due to one or a combination of the three following causes (*a*) a metallurgical flaw, (*b*) stress concentration, and (*c*) stress from excessive vibratory movement.

By metallurgical flaw is meant defective metal, such as slag inclusion, folds, injury to structure from improper heat-treatment, residual stresses, and the like. That failures in this category are becoming more and more rare is a tribute to the metallurgists.

Excessive stress-concentration may be due to faulty design or to accident. The magnification of stress at points of discontinuity or sudden changes in section is now fairly well understood and taken into account in modern design. The advance in the photoelastic art, wherein machine-part models of suitable material are examined under stress with polarized light, has added greatly to our knowledge of the magnitude of stress concentrations or stress raisers at discontinuous points, such as at sharp changes of section, holes, notches, and the like. The stresses in complicated, three-dimensional parts are not so easily determinable, and, therefore, may become greater than intended.

Accidental stress concentrations due to nicks or other damage are far more potent than is generally realized and have been the direct cause of many fatigue cracks. A sharp nick or a fine grinding or quenching crack at the right point may magnify the local stress to a value that is many times higher than the calculated stress at that point and start progressive fracture. For this reason, the search for cracks should be intensified in the neighborhood of nicks and other surface damage. If the normal working stresses are high, nicks that are almost microscopic become important. As an example, merely stoning the edges of steam-turbine blades raised their endurance to stress reversals in a fatigue-testing machine from five to ten times. Artificial nicks, such as can be made with a razor blade, can start a fracture at a considerable distance away from the theoretical location of the maximum fiber stress.

The root of a thread makes an admirable nick for unintentionally producing high stress concentrations. Thread roots are especially vicious because they are usually located at nodes or points where the normal stresses are high, for example, where pipes are screwed into heavy fittings.

In the foregoing, the dynamic forces and movements were

Presented at a joint meeting of the New York Section of the American Welding Society and the Metropolitan Section of The American Society of Mechanical Engineers, Jan. 13, 1937, New York, N. Y.

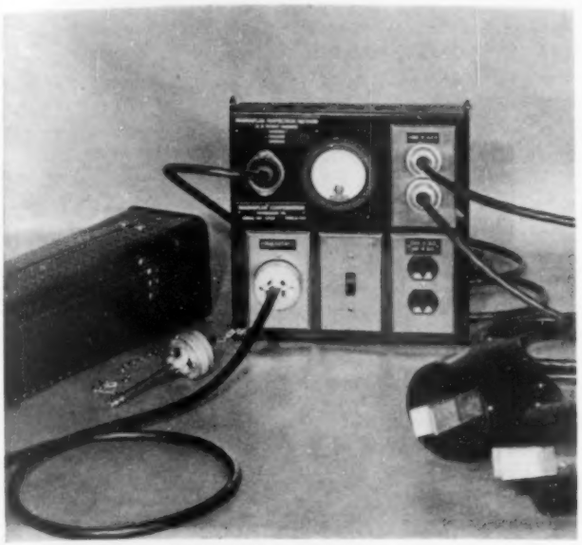


FIG. 2 PORTABLE MAGNETIZING SET

assumed to be under control and excessive stresses caused by local flaws or stress raisers. We come now to the third and probably most dangerous condition leading to excessive stresses, that due to vibratory movement beyond the anticipated range. No local flaw or nick is necessary to start fatigue cracks in this situation; the vibratory forces are sufficient to set up fiber stresses exceeding the endurance limit in perfectly sound material. When nicks or flaws do occur in combination, the situation is doubly aggravated, and the vibratory stress required to start fracture is reduced.

The problem of machinery vibration is a huge subject in itself and can only be discussed briefly here. Some knowledge of the manner in which machine parts can vibrate and set up stresses causing fracture is, however, a prerequisite for the intelligent search for cracks.

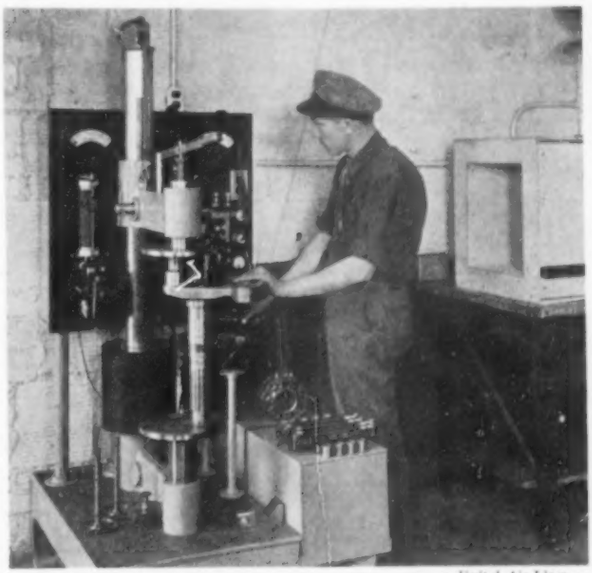
VIBRATORY MOVEMENTS CLASSIFIED

Vibratory movement is of several distinct types which fall naturally in the following classes: (*a*) forced vibration, (*b*) resonant vibration, (*c*) self-induced vibration, and (*d*) alternating movements due to temperature changes or other causes. Vibration is also classified as either linear, which usually can be observed directly, or torsional, in which no bodily displacement occurs and which usually requires stroboscopic means or other special apparatus to detect.

Forced vibration includes the deliberate and controlled straining movements that are inherent in reciprocating machinery parts such as piston rods, cranks, shafting, pedestals, and similar members, and in the shafting of purely rotative machinery, due to static loading and to centrifugal forces. In general, the magnitude of the stresses due to these types of forced vibration is more apt to be under the control of the designer and, hence, not so prone to become excessive and cause failure. An important exception, however, occurs in the case of crankshafts with bearing misalignment. The degree of misalignment is an accident, and the extent of the resulting stress reversals in the web once each revolution is more or less indeterminate. Likewise, the rotating bending stresses set up in the shafting of power machinery due to coupling misalignment or shaft distortion are a function of the degree of misalignment and, therefore, unpredictable. The crack in the web usually starts at the junction with the inner end of the crankpin. The shaft crack generally occurs at a change in diameter and is markedly influenced by the sharpness of the fillet.

All machinery, both in the complete unit and in its parts, has natural vibration frequencies that are inherent and unavoidable. These frequencies can be changed almost at will but cannot be eliminated. When the periodic reciprocating forces, due to the operation of the machine, synchronize with the natural frequency of the machine or any of its parts, the phenomenon of resonance, which is one of the greatest curses the engineer is called on to face, is encountered. Theoretically, the magnitude of vibratory movement that resonance can develop is unlimited; actually the amplitudes increase until something happens.

The dynamics of resonant vibration are thoroughly understood, but the practical calculations to predict or to avoid or to control it are a far different matter. The mathematical processes become extremely complex and involved. However, great headway has been made. The former mysterious cracking through of Diesel-engine shafting, which was so long a puzzle, is now rarely encountered. When torsional resonance was recognized as the cause, a calculation technique and special



United Air Lines

FIG. 3 MAGNETIZING OUTFIT USING HEAVY CURRENT

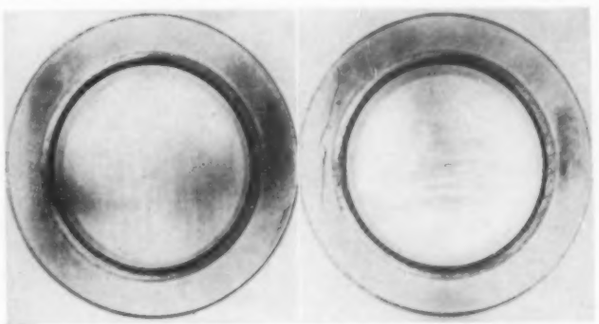


FIG. 4 RING BEFORE POWDER WAS APPLIED

FIG. 5 CRACKS IN RING SHOWN BY POWDER

vibration apparatus, such as the Geiger torsiograph, were developed to detect and to avoid the critical condition.

The explosion of steam-turbine disk wheels is one of the most outstanding examples of the results of resonant vibration. These occurrences were very baffling until an unusual type of resonance was demonstrated to be the cause. Now, through brilliant dynamic analysis in design and careful periodic inspections, the difficulties are practically eliminated. Many cases of resonance in machine parts are still with us, some of which are extremely difficult to predict and avoid. Examples are steam and oil piping on turbines, turbine blading, foundations, and critical-speed vibration of rotating parts.

Sometimes an object can be made to vibrate violently at its own natural frequency, without the necessity for supplying periodic forces at that frequency. This is called self-induced vibration. The simplest example is the violin string, which vibrates at its natural frequency without any regard for natural frequencies in the bow. Organ pipes furnish another example. All that is necessary is a steady force input. If the natural frequency is changed by lengthening, tightening, or otherwise altering, the system simply vibrates at the new frequency. The singing or squealing water tap is a third example.

Many failures of turbine blading are believed to have been caused by fatigue from such self-excited vibration when the blades flutter in the steam flow. Other examples are the failure by fatigue of thin nozzle vanes and some failures in valve parts and condenser tubes. The fact, that in many such failures the natural frequencies of the parts bore no relation whatever to the speed of rotation or any multiple thereof or to any other periodic force frequency, supports the belief that the vibration was self-induced.

FIG. 7 ENGINE PISTON WRECKED DUE TO FATIGUE CRACK

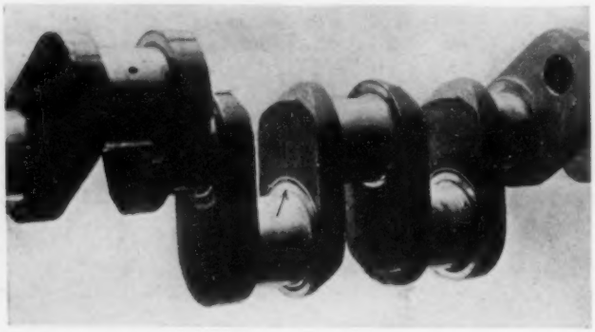


FIG. 6 CRACK IN CRANKSHAFT WEB

FIG. 8 FATIGUE CRACK DISCLOSED BY POWDER

Examples of the propagation of cracks by thermal stresses or cyclic movements due to temperature changes are difficult to prove, yet the growth of certain types of crack requires some such explanation. The Trevelyan rocker furnishes an interesting example of the manner in which a large mass can be set in periodic movement by rapid expansion and contraction due to temperature changes by conduction at a sharp contact. Although few supporting experimental data are available, some such phenomenon may cause the spread of cracks in parts subject to heat fluctuations.

FATIGUE CRACKS—THEIR PROPAGATION AND APPEARANCE

The propagation of the true fatigue crack is relatively slow. It is a function of the magnitude of the stress reversals and the number of reversals in a given time. With careful, periodic inspections, usually ample warning is given before final rupture occurs. The smaller the vibratory movement and stress-reversal range, the finer will be the surface of the fracture and the harder to detect.

The surface of the fatigue crack generally shows the characteristic shell-like markings (Fig. 1), indicating the progress and the vibration history. Sometimes, these markings are so fine that they can only be seen in reflected light at a particular angle. As the cracks progress, the section modulus at that zone changes, and, hence, the natural frequency is lowered. This may throw the part out of resonance with the disturbing force and diminish the amplitude. Foreign matter and a viscous film in a crack have restored the original natural frequency, increased the vibration amplitude, and also broadened the tuning. Often the mode or direction of vibration changes as the crack progresses. This causes the crack to deviate from a flat plane and form a curved fracture surface. Often, changes in intensity and other characteristics of the vibration can be read in the surface markings just as the annular rings in a tree section show its growth history.

After a specimen has withstood several million stress reversals without cracking, the usual assumption is that it has been subjected to stresses well below the endurance limit and should last indefinitely. However, fatigue cracks have been found in parts that had already been subjected to many billions of reversals. For example, a particular turbine blade vibrating at a natural frequency of 300 cycles per sec undergoes a little over a million reversals in an hour of running. Yet this blade failed only after four years' operation, representing 30 billion reversals, a situation frequently encountered.

A reasonable explanation is that the conditions under which the greater stresses causing fatigue occurred were only intermittent and transitory, as during the starting up and shutting down of the unit. This is particularly true of oil and steam lines affected by vibration from unbalance, which may tune in and vibrate wildly only while the unit is passing through some particular speed. Thus, years may be required to develop a fatigue crack. Turbine operators have an old saying that units kept on line longest give the least trouble.

Despite the advances made in the design and metallurgical arts toward the creation of equipment that will be failure-proof, so many factors of an accidental and unpredictable nature remain to enter the picture that no substitute has yet been evolved to replace frequent, thorough inspection.

DETECTION OF CRACKS

Years ago, the whiting test became popular for the detection of suspected but invisible cracks. By this method, the suspected area was coated with a penetrating oil, dried, and covered with a whiting mixture. The oil, seeping out of the crack, stained the whiting and disclosed the crack. When properly used, this method is still valuable, within limitations, especially for coarser, well-developed cracks. However, it is not infallible and often will not reveal cracks demonstrated by other means. It is practically useless for the fine shallow surface cracks often encountered on finely finished parts and for more extensive cracks in compression.

The acid-etch method to make the crack visible has been fairly successful, where the application is appropriate. However, a thorough job requires a polishing of the entire area suspected and sufficient time for the etching. Neutralizing with a caustic is generally required afterward. With many large-scale applications, the etching method is entirely too tedious and costly.

Crack detection in ferrous materials by magnetizing the part and applying a finely divided magnetic powder has now been in successful use for several years. The magnetic-flux leakage at even the finest crack attracts the powder in its attempt to bridge over the discontinuity and makes it visible. Three methods for magnetizing the object for inspection, each having its own field of usefulness and advantages, are available. In the first, the part is magnetized by two electromagnets, the poles of which are placed on the object to establish flux in the area being examined. This system is particularly useful for the testing of small, light parts on a production basis, but the magnets may also be used on large, stationary objects. A portable set for this purpose is illustrated in Fig. 2, complete with resistance and panel. The second method magnetizes the object by wrapping it with several turns of cable carrying a relatively heavy current. The current is usually supplied by a small, portable electric-welding set having a capacity of from 200 to 400 amp. From 500 to 2000 ampere turns are generally found sufficient, even for the largest parts. With the third method, a heavy current is passed directly through the piece under test. The application of the current need be but momentary, as the residual magnetism is usually sufficient. This method is especially advantageous for small parts on routine testing, and particularly where the anticipated flaws are in the direction of the current flow.

A magnetizing set using current is shown in Fig. 3. The

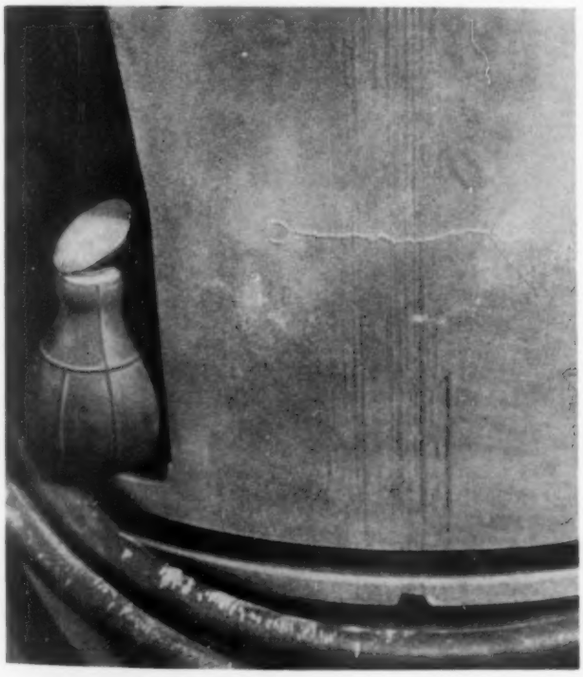


FIG. 9 OLD CRACK IN PISTON SKIRT, SHOWING PLUGGED STOPPER HOLES

FIG. 10 PISTON MAGNETIZED BY TOROIDAL WINDING

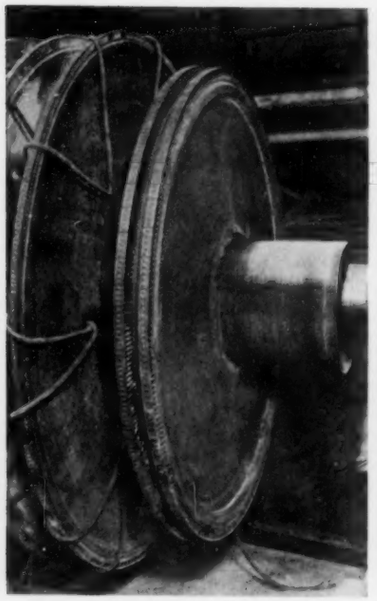


FIG. 11 STEAM-TURBINE DISK WHEEL MAGNETIZED BY TOROIDAL WINDING

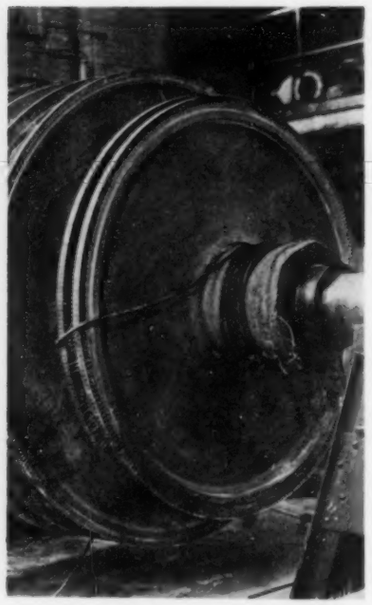


FIG. 12 TURBINE ROTOR MAGNETIZED BY SOLENOID-TYPE WINDING

piece to be tested is placed between the upper and lower electrode plates.

The magnetic powder is applied either wet or dry, as convenient, and either method is effective. The dry powder, dusted or sprinkled lightly over the surface with a shaker or a spray bulb, is best suited for covering large areas, such as castings, shafting, turbine blading, and disks. This magnaflux powder can be procured with a light greyish white coating. It dusts on readily, and the color contrast with dark surfaces makes the crack stand out prominently.

The black magnetic oxide of iron, in the form of an extremely fine, impalpable powder, is better suited for the wet method, in which a light oil is used as the carrier. Small parts can be tested by immersion in a bath of this mixture. The small magnetic particles in suspension readily collect at the crack, which shows up as a fine black line. The mixture can also be flowed on the surface of large parts, such as shafting and turbine disk wheels. The particles are mobile in the oil film and will concentrate at a crack. The black oxide is particularly suited for the detection of very fine surface cracks in polished surfaces. Fig. 4 shows a hardened and ground ring containing two cracks that are invisible. After magnetizing and treating with the black oxide powder, the cracks are unmistakably evident, as illustrated in Fig. 5.

TYPICAL EXAMPLES OF FATIGUE CRACKS

The typical fatigue crack in the web of a crankshaft due to stresses from bearing misalignment is shown in Fig. 6. The otherwise invisible crack is made evident by the line of grey powder as indicated by the arrow. Large Diesel-engine crankshafts and steam-engine shafts are easily magnetized to show up such cracks by removing the connecting rod and passing a few turns of cable around the web or crankpin.

In Fig. 7[1] is shown the wreck of a large gas-engine piston. Sometime earlier, a failure of the cooling oil in the top of the piston occurred, and the consequent heating and expansion caused a severe binding, thus setting up large reciprocating forces at each revolution until the engine could be shut down. To aggravate matters, a definite zone of weakness extended through the inspection handhole and around the skirt, due to stress raisers at the tapped holes for the flange studs and at the sharp fillet made by the shotgun boss on the interior. The accident occurred without warning during normal operating conditions, and subsequent investigation revealed definite evidence of progressive fracture.

An inspection for cracks in the remaining pistons resulted in the rejection of four. In Fig. 8, a true fatigue crack is disclosed by the white magnaflux powder, in the exact location where the wrecked piston was fractured. This crack could not be seen by the eye alone and probably would have escaped detection by the whiting method.

On another piston, an old crack was disclosed by the test, as shown in Fig. 9. Although this defect was invisible and unsuspected by the operators, its existence must have been known sometime earlier, as the drilling and plugging at the ends of the crack to stop its progress were plainly evident. Incidentally, the crack extends beyond the plug at the right.

Plugging such cracks may only serve to aggravate matters. The crack may extend a considerable distance beyond its visible end or the end as located by whiting. If the hole is not drilled beyond the extreme end, it is useless. If such a hole is plugged, the drifting or wedging action may only make the crack spread more rapidly. The magnaflux method is valuable in determining the true limits of a crack which can be arrested by a stopper hole. If possible, the crack should be rigidly bound together at the middle by shrink links or other means, to prevent further "working," as this movement causes the crack to spread. The movement required to start a fatigue crack is surprisingly small, even truly microscopic.

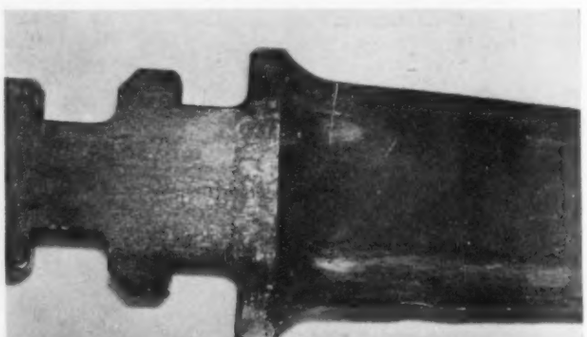


FIG. 13 CRACK IN STEAM-TURBINE BLADE DISCLOSED BY MAGNAFLUX POWDER

PITFALLS TO BE AVOIDED IN CRACK DETECTION

Merely to magnetize the object, sprinkle powder, and watch for cracks is not sufficient in carrying out a magnaflux test. Pitfalls must be guarded against, lest cracks that do exist es-

[1] Photographs of Figs. 7, 8, 9, 10, and 14 are the work of Ayres A. Stevens.

FIG. 14 "MAGNETIC WRITING"

cape detection, or false indications of cracks and flaws that do not exist cause the object to be needlessly condemned or mutilated.

Although the magnetic-powder test method has now been in successful use for several years, its earlier application has been largely limited to small objects easily magnetized in a proper manner. Considerable experience has recently been acquired on larger and more complex parts which indicates that with proper attention to certain fundamental rules in magnetizing, full confidence may be placed in the inspection for cracks.

Mere strength of magnetic field does not insure the disclosure of a crack—in fact experience has shown that, under certain conditions, too much flux density is objectionable. That the direction of the flux lines be that best suited to show up the crack is far more important. If the crack is located at a pole where the lines come out at right angles, the powder has no way of knowing that a crack exists, as its function is to bridge the leakage at a crack.

As a specific example, a circumferential crack in the skirt of the piston shown in Fig. 10 would not attract the powder when the piston was magnetized by wrapping the cables in solenoid fashion at one end. The reason was evident when it was found that, due to the conformation of the casting, the flux lines were forced out at right angles to the surface at that point. When the piston was properly magnetized to avoid poles at the surfaces being examined, the cracks readily attracted powder from some distance away in the air. Incidentally, the strength of the field required was reduced to a very small value. The type of wrapping used is called the toroid method and is similar to the winding on a doughnut-shaped core because it produces a closed flux circuit.

The application of the toroidal winding to steam-turbine disk wheels is shown in Fig. 11. By this method, the flux lines are largely circumferential, and the most minute cracks having any radial component are readily disclosed. Even circumferential cracks are sufficiently irregular to have some radial component.

In Fig. 12 the solenoid method of wrapping is shown, which is especially suited for detecting cracks and flaws in the shaft itself.

Certain other methods of wrapping, in the attempt to favor the circumferential type of crack, had the effect of forcing the lines of flux out at right angles to the surfaces of the disk. The powder merely flew directly to the surface and stuck there in streamers, regardless of the presence of a discontinuity.

Fig. 13 shows a crack in a large turbine blade that was made visible by the magnaflux powder. One of the most effective fields of usefulness for this kind of test lies in the detection of cracks in steam-turbine blades and buckets, which are so prone to be invisible to the unaided eye. The author's first experience with this method of inspection was in connection with a research on blade failures that was being carried out a number of years ago at the South Philadelphia works of the Westinghouse Electric & Manufacturing Co. The method soon demonstrated its value and, in addition to its use in the field, was made a part of the shop inspection routine. At first the blades were checked individually, then methods for inspecting an assembly in the rotor in the field by electromagnets were developed.

Puzzling markings, where the powder indicated flaws or cracks which were found not to exist, have been encountered in the past. As a matter of interest, Fig. 14 is included to show how some of these markings come about. The hieroglyphics are due to the powder collecting on spots at which local residual magnetism has been set up by simply drawing a piece of iron rod along the magnetized surface. To prove that such marks are false, reverse the polarity, which produces a "negative" mark; that is, the powder falls away from the mark and clings to the sides. A number of other conditions exist which might give false indications without sufficient experience.

A crack discovered in the front axle of a racing car just before a recent automobile race is shown in Fig. 15. The magnetization in this case was accomplished by passing a heavy current directly through the part. This crack is absolutely invisible to the unaided eye. Apparently the sharp fillet at the junction of the stub axle and the bracket set up an excessive stress concentration. The discovery of this crack probably saved the driver's life.

From the examples described, the magnetic-test method is seen to be applicable to practically all types of machinery and their individual parts. Properly used, it has proved to be an extremely valuable tool in the inspection of equipment insured by our company.

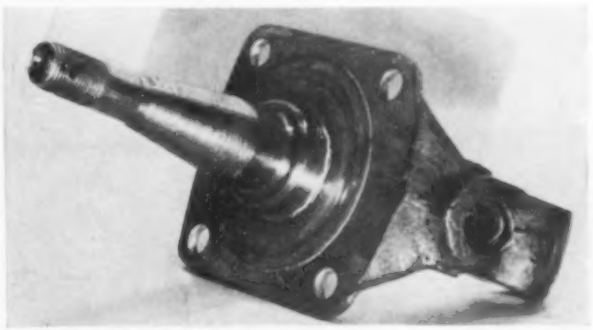


FIG. 15 CRACK DISCOVERED IN FRONT AXLE OF RACING CAR

MAGNAFLUX INSPECTION *of* BOILER DRUMS *and Unfired* PRESSURE VESSELS

By R. F. CAVANAGH

ENGINEERING DEPARTMENT, FIDELITY & CASUALTY CO. OF NEW YORK

THE NONDESTRUCTIVE magnetic-dust method of discovering invisible cracks and defects has been successfully applied to steam boilers and unfired pressure vessels. This dust is manufactured by the Magnaflux Corporation and is generally known as magnaflux powder. It is basically metallic iron that has been finely ground to pass a 100-mesh sieve. The individual particles are spindle-shaped rather than globular to obtain the better polarization which facilitates their grouping or arranging at a crack or defect. This grouping is facilitated by specially coating the particles to prevent rusting and to add lubricating and insulating properties that retard packing and sticking. When dry, the powder particles are effectively insulated from each other electrically. An infinity megger reading should be obtained even with the electrode terminals buried only a fraction of an inch apart in a can of powder.

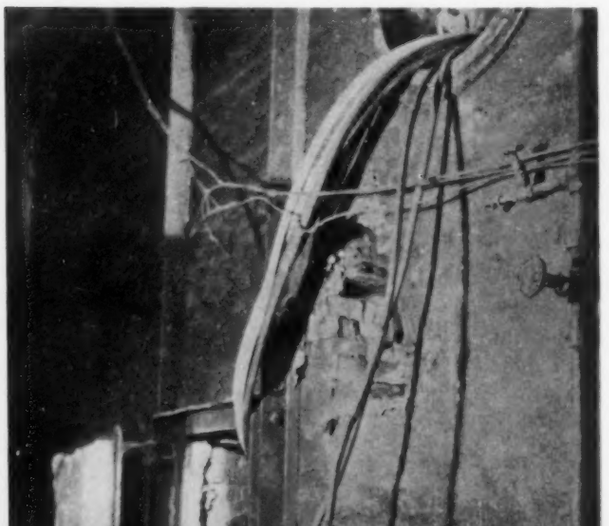


FIG. 1 MAGNETIZING MULTIPLE-DRUM WATER-TUBE BOILER BY PASSING CABLES THROUGH TUBES OF ONE DRUM AND BACK THROUGH MANHOLE OPENING OF SECOND

In applying the powder, the best results are obtained by using a common bulb spray, such as is used for spraying powder on plants, with a perforated aluminum nozzle that is set at an angle. When using the powder in a confined space, an approved type respirator is recommended to prevent possible irritation of the mucous membranes or the eyes.

The bulb should not be filled to more than half of its capacity. For vertical and particularly for the underside of horizontal surfaces, practice will enable the operator to "lay" the powder in place, by a combination of throwing and light rapid squeezing of the bulb. Best results are obtained when the small puff of powder just reaches the surface under investigation. If the air blast is too hard, the powder is likely to be blown from any defect that may be present. For horizontal surfaces, sufficient powder is dispersed by giving the bulb a slight shake.

By carefully observing the factors involved, a fairly accurate estimate of the depth of a crack can be made. The variation in the quantity of powder adhering to the crack corresponds with the variation in its depth.

To permit proper inspection, all interior and exterior seams must be exposed and made accessible for examination either directly or with a mirror. The seams should be wire-brushed and any thick scale or sediment removed. A perfectly clean bright surface is not necessary, as the powder will reveal cracks through a light scale or rust coating, but all loose rust or scale should be removed.

Where riveted seams are used, some rivets should be removed to permit detailed examination of the rivet itself and the sides of the hole, especially the shell plate between the inner and outer butt straps. Ordinarily four or five rivets are removed from each longitudinal seam and two or three from each girth seam. Those rivets are selected for removal which show indications of past leakage or repeated calking. Removing at least one rivet near the bottom of each girth and head seam is also advisable.

Unlike the magnifying and photographic methods that require careful polishing and etching in and around the rivet hole to make cracks visible, the magnaflux method requires no preparation of the hole. If a crack is there, the powder will make it visible to the unaided eye several feet away.

Boiler shells or drums are magnetized by winding several

Presented at a joint meeting of the New York Section of the American Welding Society and the Metropolitan Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Jan. 13, 1937, New York, N. Y.

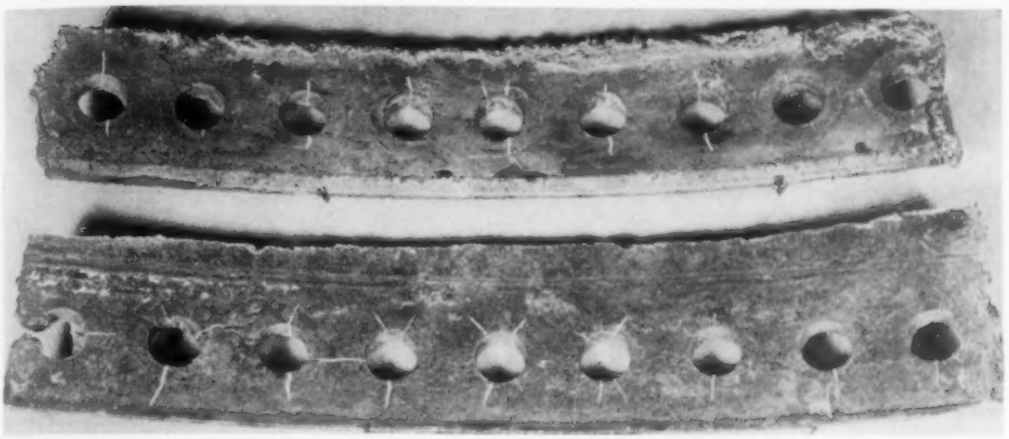


FIG. 2 TYPICAL EXAMPLE OF CAUSTIC-EMBRITTLEMENT CRACKS IN GIRTH SEAM OF HORIZONTAL TUBULAR BOILER

turns of flexible cable through or around them. The cable is energized by an ordinary portable electric welding set. The current value is dependent on the size of the shell or drum and the number of turns of cable, the average being about 2000 ampere turns. For multiple-drum water-tube boilers, a convenient method is to wind two drums at one time by passing the cable across through circulating tubes and out the manhole opening of the second drum (Fig. 1).

Where each end of a boiler drum or shell has a manhole opening, the cable is wound longitudinally through the manhole openings and around the outside of the drum, and, in some cases, winding the cable circumferentially around the shell or drum is more convenient. In general, a magnetic field should be set up within the shell or drum at right angles to the direction in which cracks or defects are expected to be found. However, most cracks running in the general direction of the lines of flux present sufficient transverse components to prevent their escaping detection. Where incipient cracks of microscopic dimensions are being searched for, magnetization in both directions is necessary.

Winding shells or drums longitudinally is usually more convenient, and, in addition, the flux direction will be the most favorable for investigating the greatest area. As this flux direction will be less favorable for detection of circumferential cracks, investigation in that direction can be conveniently made by portable electromagnets.

Portable electromagnets are also used where magnetization in the desired direction is not practical by the cable-winding method. For the head seams, one magnet is placed on the head and the other on the shell in a radial line with the first and approximately 1 ft away. A similar setup is effective for other girth seams. The magnet poles on either side of the seam should, of course, be checked. Portions of the drum of a water-tube boiler farthest from the coil, particularly drums with blank heads where the cable has been passed through tube holes instead may not have sufficient flux density. In such cases, portable electromagnets can generally be used to cover these local areas.

The best method for determining whether the flux density is sufficient is to observe how the powder collects at the edge of the rivet head against the shell or strap, as this, so far as the powder is concerned, is a crack. With some practice, the manner in which a light dusting of powder clings to any surface or edge will indicate whether the magnetization in the right direction is sufficient.

Generally the tendency will be to overmagnetize rather than undermagnetize the drum. Often, the residual magnetism after shutting off the current is sufficient to show up cracks. If the flux is too great or flux lines come into the air at right angles, the powder will fly directly to the surface and collect in "streamers" or hairs that stand out from the surface. Cracks will then not show up properly. In such cases, the residual-flux way gives best results, particularly for those portions of the head inside the loop.

Cracks are sometimes caused by the local concentration of stresses that are set up by breathing action or thermal expansion and contraction. This type of crack follows the general behavior of fatigue cracks, often preferring a surface notch, such as is provided by the rough surface or porosity of a poorly laid bead of weld, for its starting point. The general subject of fatigue cracks is discussed by T. C. Rathbone in another paper in this issue. (See pages 147–152.)

CAUSTIC OR HYDROGEN EMBRITTLEMENT

All cracks radiating from a rivet hole are not necessarily embrittlement cracks, and recognized authorities are not in agreement as to what is or is not embrittlement. The most reliable information indicates that cracks may start at local areas that are stressed beyond the yield point in the presence of a concentration of caustic, silica, and heat. By some mysterious process, nascent hydrogen, which is liberated by oxidation

FIG. 3 CRACK IN $^{15}/_{16}$-IN. PLATE FORMING SHELL OF DIGESTER

under these conditions, has the power to penetrate the intercrystalline cementite and cause cracks.

Many cracks found at rivet holes by magnaflux were definitely not embrittlement cracks but were caused by mechanical processes, such as excessive drifting and riveting pressures in manufacturing, excessive calking, or by fatigue from breathing. Microscopic examination of the crack with suitable etching reagents may disclose its origin, but here again some confusion exists, as examples of embrittlement cracks are found transversing the crystals instead of being intercrystalline, and portions of stress-fatigue cracks may follow crystal boundaries instead of being transcrystalline.

Generally, irregular, branching and discontinuous cracks that radiate in all directions, pass each other, and form islands, are indicative of embrittlement, especially where caustic concentration is found between plates. Stress cracks, on the other hand, have a general tendency to progress in a more direct line and usually are not as numerous, sometimes occurring as a single crack between rivet holes.

Fig. 2 is an example of embrittlement cracks that occurred in the girth seam of a horizontal tubular boiler which was found to be a typical case of caustic embrittlement. This boiler had been in service less than four years, was built according to the requirements of the A.S.M.E. Boiler Code, and received the required inspection during construction. It was of butt and double strap, quadruple-riveted seam construction. The condition was obviously caused by improper feedwater treatment.

Fig. 3 shows part of a 5 × 20-in. plate that was cut from a $^{15}/_{16}$-in. shell plate of a hammer-welded digester, which was 8 ft in diameter and 25 ft long and operated under a pressure of 110 lb. One crack, more than 14 in. long and reaching the maximum depth of $^{3}/_{4}$ in. was revealed by magnaflux on the interior surface. This crack was not visible under a four-power magnifying glass. Several smaller cracks were also found. Imperfect seams in this digester were easily demonstrated by magnetizing with portable electromagnets. Here, the thin edge of the scarfed joint had either chilled or else scale prevented making a perfect bond.

The extent of the imperfect seams and the cracks were investigated further by trepanning to obtain a small coupon. This investigation confirmed the previous estimate of the depth of the cracks, and also revealed that they were caused by caustic embrittlement.

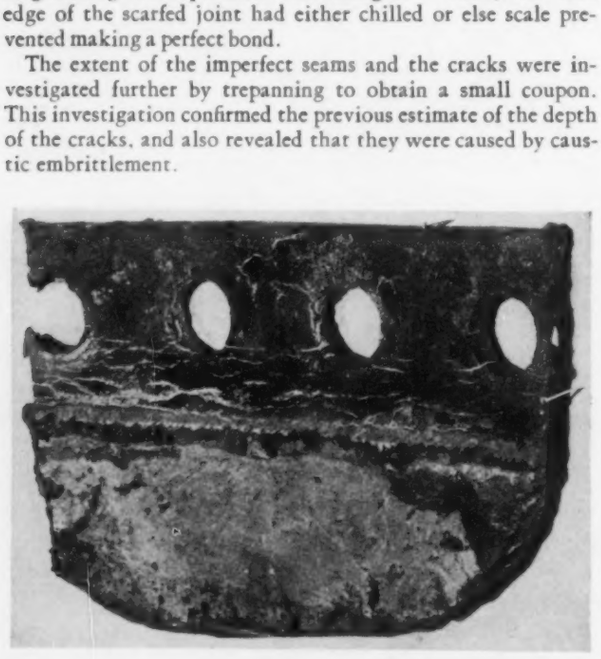


FIG. 4 PART OF PLATE FORMING GIRTH SEAM OF HORIZONTAL-RETURN TUBULAR BOILER

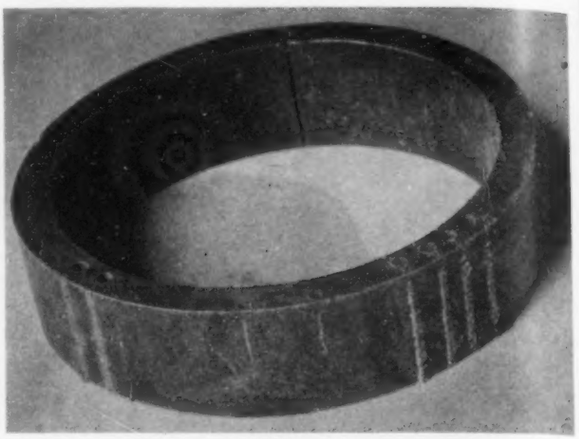


FIG. 5 EXAMPLE OF DETECTION OF HIDDEN DEFECTS BY MAGNAFLUX PROCESS

Magnaflux inspection was immediately made of the other two digesters in this particular plant, after the conditions previously mentioned were disclosed, and they were found in practically the same condition. All three were condemned for further use as pressure vessels and were immediately replaced by new ones.

OTHER TYPES OF DEFECT REVEALED

Fig. 4 shows a piece of plate taken from the girth seam of a horizontal fire-tube boiler. In this case, the operator of the boiler laid a bead of weld along the seam, thus forming a fillet on the inside to stop leakage. The large cracks at the weld had developed through to the outer surface, and a bead of weld 6 in. long had been applied to seal it. A magnaflux test revealed that the crack continued intermittently for 20 in. At some points, the larger crack penetrated to within $^{1}/_{32}$ in. of the outer surface of the plate. While this method of repair could not be approved, the test did prove conclusively that the crack was considerably longer than could be detected with the eye.

Cracked ligaments are frequently found in the top tube sheet of the waste-heat type of vertical fire-tube boiler that is used in connection with the manufacture of water gas. The flame or hot gases are applied in periodic cycles recurring every few minutes. This sets up a cyclic expansion and contraction or breathing which is very conducive to the start and propagation of cracks. Usually such cracks have been repaired by welding. New cracks often develop subsequently alongside the weld, due to improper annealing and continued breathing. On one occasion of this type, nearly fifty cracked tube-sheet ligaments were found, which, had they progressed farther, would have freed a section of the sheet with its tubes.

Nozzles and fittings on digesters and other pressure vessels of the welded type cannot generally be X-rayed satisfactorily. The magnaflux process is, therefore, particularly useful for this application as the powder will collect over flaws or voids in the weld even when these defects are considerably below the surface.

One of the outstanding advantages of this over other methods adaptable to field investigations is its ability to reveal flaws and other defects beneath the surface of the material faithfully. The ring in Fig. 5 was prepared by drilling holes of several different diameters in the ring and at different distances from the outer edge of the ring. Applying the powder very clearly outlines these holes on the surface of the ring.

Cutting Steel Underwater

By CHARLES KANDEL*

THE cutting of steel underwater with a properly designed gas torch is as simple an operation as on the surface. In the hands of a skilled operator adequately trained in this work, such a torch will cut steel with the same degree of speed and accuracy as is possible on the surface, excepting only for the handicaps incidental to diving such as, the weight and bulk of the diver's rig, the poor visibility underwater, the irregular footing available, the cramped or awkward position the diver may be compelled to assume while at work and the strain and discomfort resulting from excessive pressure or low temperature surrounding him.

The basic principles of a gas torch for underwater cutting include: (1) A device for maintaining a continuous artificial atmosphere around the flame, and, (2) A mixer designed to resist flashback against the water pressure surrounding the flame and the cycles of explosion resulting from the breaking up of the generated superheated steam into nascent oxygen and hydrogen and their recombination into water vapor.

While almost any torch can be used to "burn a hole" in steel underwater after several attempts, only a properly designed torch can be used for continuous cutting of steel of any thickness at any depth anywhere a diver can operate.

The first practical application of such a torch in the U. S. was made by Commander Edward Ellsberg in 1926 in connection with salvage operations under his direction resulting in the raising of the U. S. Submarine S-51 from a depth of 138 feet, for which he was awarded the Distinguished Service Medal.

In 1927, the torch found its first application in industrial work and since then has been used on a wide range of construction, demolition and salvage projects under widely varying conditions with uniformly good results.

In 1936 several changes in design were made resulting in rather startling improvements in the speed of cutting. On one project entailing the cutting of interlocking sheet steel piles at a depth of 30 feet, a cutting speed of 30 sheets per hour was attained. This is equivalent to approx. 30 lineal feet of $^3/_8$ inch steel of single thickness and approx. 10 feet of quadruple thickness averaging $1^1/_2$ inches, the total being equivalent to over 60 lineal feet of $^3/_8$ inch single thickness.

The following are typical projects on which this torch has been used on industrial work during the past 10 years:

Cutting up a new highway bridge which had just been maliciously dynamited.

Cutting up a railroad bridge washed out in a flood.

Fig. 1—Plan of Interlocking Steelsheet Piles. Over 2000 of These Were Cut in 40 Days

Fig. 2—Cutting Steel in Deep Water

Cutting up a trash rack at intake of a large hydroelectric plant.

Cutting up the steel hull of a sunken vessel.

Cutting up 48-inch girders forming the roof of the work chamber at the bottom of a caisson 95 feet underwater.

Numerous engagements entailing a total of about 50 cofferdams containing over 5000 interlocking sheet steel piles including several cofferdams in which the sheets had been bent and twisted as a result of a flood.

These projects were located in widely scattered points and covered a wide range of conditions of depth, both extremely low and high temperatures of water, strong tides or currents, fresh and salt water with both good and very bad visibility, on hard bottoms as well as bottoms which might be classified as quicksand. Every project undertaken was completed as planned and where the conditions surrounding the work were accurately determined in advance, the final cost of the cutting was very close to the estimate submitted.

A study is now being made of the possibility of applying this torch to the cutting of alloy steels underwater as a means of reducing the injurious effect upon the molecular structures of the alloys, and it is hoped some valuable data on this subject may be available in the near future.

* President, Craftsweld Equipment Corporation.

Fig. 1—Hard-Facing a High-Pressure, High-Temperature Steam Regulating Valve Disk

Steel Hard-Facing Procedure

By E. E. Le VAN†

Step-by-Step Instructions for Hard-Facing Steel with Alloys of Cobalt, Chromium and Tungsten

USEFUL and economical applications of the hard-facing process have been described many times in the past. Recent researches and developments have brought out certain points in connection with the actual technique that make it desirable at this time to present a detailed procedure for hard-facing steel. The information will prove of value to both veteran and apprentice welding operators.

Although most welding operators are familiar with the general procedure for hard-facing steel by the oxyacetylene process, many of the suggestions may help to solve some of the problems encountered in connection with difficult jobs.

To illustrate the procedure in its simplest form, and yet most detailed manner, the application of hard-facing alloy to a small strip of steel will be described. The steel sample is approximately $1^1/_4$ in. wide, $^3/_4$ in. thick, and 8 in. long. Although this simple piece was selected to illustrate the various operations, the instructions apply generally to most types of parts to be hard-faced. A knowledge of general welding practice plus careful observance of the special instructions and precautions given here, is all that is necessary to produce an excellent hard-facing job.

† General Sales Manager, Haynes Stellite Company.

Preparation of the Part

Step No. 1.—Thoroughly clean the surface of the steel part to be hard-faced by grinding or machining until it is free from all dirt, scale, grease or other foreign material. Round off all sharp corners. If a hard-faced edge or corner is to be subjected to shock, as on a punch, a shear blade or a die, the steel should first be machined as shown in Fig. 2 (left). The support given the hard-facing alloy will then adequately withstand a shock applied vertically, or parallel to the thicker dimension of the alloy deposit. The ratio of widths should be as shown: i.e., 2 or 3 to 1.

If no severe impact is to be encountered, angles or corners to be hard-faced should be machined as in Fig. 1 (center), which shows the method of shaping a steel exhaust valve seat insert ring prior to the application. If the wear-resistant alloy is to be applied to a longitudinal area as on a rolling mill guide, the parts should be grooved with radii of the same length as the depth of the groove, as shown in Fig. 2 (right).

If it is impossible to grind or machine the part, it can be filed. In any case, the steel surface on which the hard-facing alloy is to be deposited *must be clean*.

Preheating

Step No. 2.—For medium size parts preheat with a neutral welding flame to about 800 deg. F. This is a

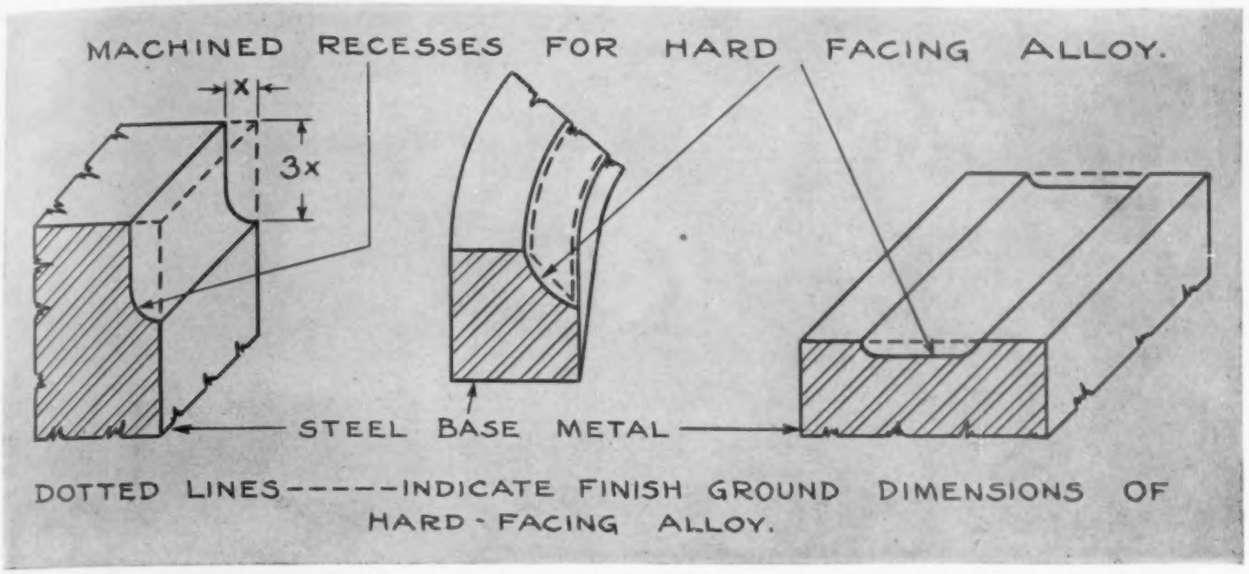


Fig. 2—Sectional View Showing Method of Machining Steel Edges and Corners Preparatory to Hard-Facing When the Part Is to Be Subjected to Shock or Impact

very faint red heat, visible only without goggles in a darkened room. For large parts preheat in a furnace. For small parts—preheat with the welding flame. It is economical to preheat in a furnace when such equipment is available, unless the part can be preheated quickly and thoroughly with the blowpipe flame. Do not, however, preheat to a temperature higher than the critical temperature of the steel to be hard-faced, or to such a high temperature that will cause the metal to scale.

Flame Adjustment

Step No. 3.—Adjust the flame so that it has an excess of acetylene. The total length of the excess acetylene feather should be about three times as long as the inner cone measured from the end of the welding tip, as shown in Fig. 6.

The excess acetylene flame prepares the steel surface by causing an extremely thin surface layer to melt, giving the steel the watery, glazed appearance known as "sweating." Production of such a "sweating" condition is necessary for the successful application of this hard-facing alloy to steel, and it can be produced only by an excess acetylene flame as shown. Furthermore, unless an excess acetylene flame is used, the alloy will not spread uniformly and will become porous.

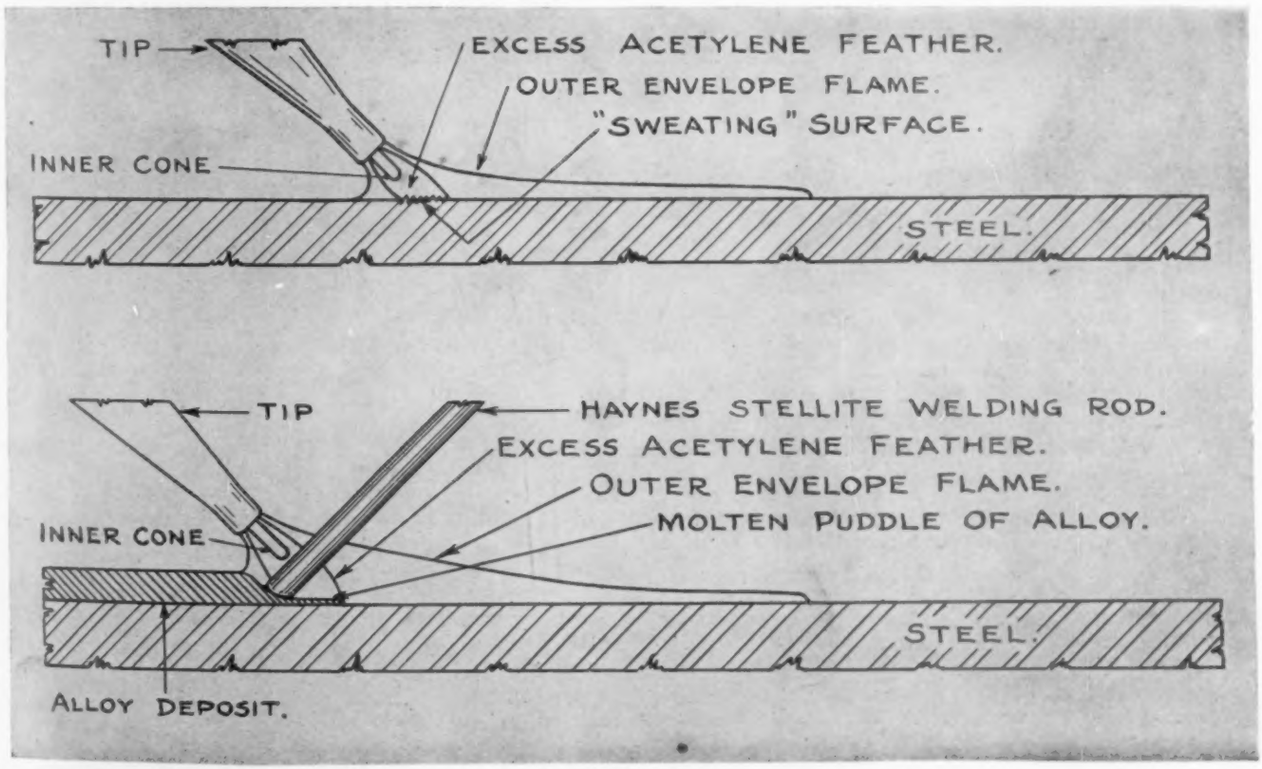


Fig. 3 (Top)—Conditions of Flame Position and Regulation to Produce "Sweating." (Bottom)—Approximate Relationship of Tip, Rod, Puddle and Base Metal During Hard-Facing

Producing "Sweating"

Step No. 4—Hold the blowpipe so that the excess acetylene flame is directed at an angle of from 30 to 60 deg. to the steel surface. The tip of the inner cone should be about $^1/_8$ in. from the steel. Keep the blowpipe in this position until the steel under the flame suddenly becomes glazed, indicating that an extremely thin surface layer has melted. This is the condition known as "sweating." The extent of the "sweating" area will vary according to the size of the welding tip, but for a medium size tip, the steel should "sweat" for a distance extending about $^1/_4$ in. around the excess acetylene feather. The steel part is now ready for the application of hard-facing alloy. See Fig. 5.

Beginning the Application

Step No. 5.—Withdraw the flame just enough so that the end of the hard-facing welding rod can be brought between the *inner cone* of the flame and the hot steel. The tip of the *inner cone* should just about touch the rod and the rod should lightly touch the "sweating" area. The end of the rod will then melt and form a puddle on the "sweating" steel surface. If the first few drops foam

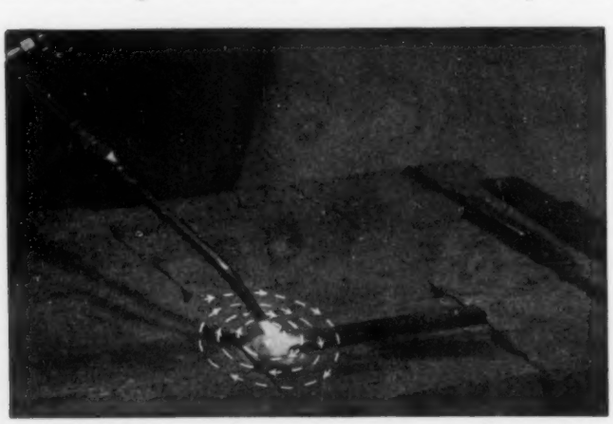


Fig. 4—Most Medium Size Parts Can Be Preheated with a Neutral Welding Flame Before Hard-Facing. The Arrows Indicate Approximate Flame Motion for Preheating

or bubble, or do not spread uniformly, the steel is too cold, and should again be brought to the full "sweating" temperature described in Steps Nos. 3 and 4.

Continuing the Deposit

Step No. 6.—Spread the molten alloy over the "sweating" area by removing the rod from the flame and directing the flame into the puddle. Return the rod to the flame and melt off more alloy into the puddle, as required.

Now direct the flame so that part of it plays only on the edge of the puddle to keep it molten and part of it plays on the steel surface adjoining the puddle. As the steel reaches the "sweating" heat, the puddle of hard-facing alloy will spread over the "sweating" area. As it spreads bring the rod quickly into the flame again, and with the end of the rod touching the puddle, melt more alloy into the spreading puddle. Continue these steps steadily until the desired area is coated. See Fig. 3 (bottom) and Fig. 8.

With a little practice, the correct amount of hard-facing alloy can be added to make the deposit the desired thickness, and it is better to do this in one operation than to go back over the whole job to add another layer of alloy. During the operation, the flame can be repeatedly moved back to melt just a thin surface layer of the deposited alloy in order to smooth out high spots just behind the molten puddle. This should be done quickly

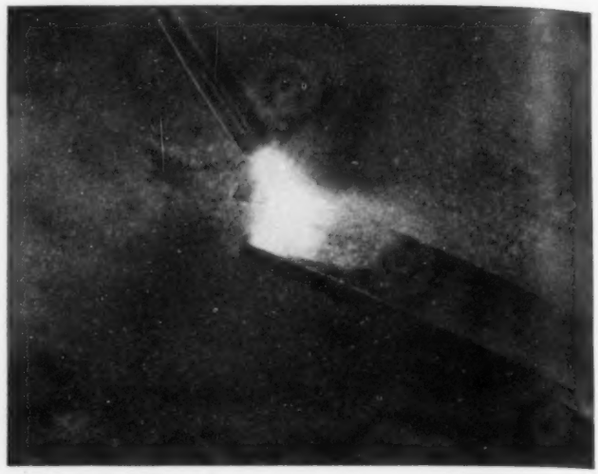


Fig. 5—After Preheating, and with Excess Acetylene Flame Adjusted, "Sweating" Is Started with Blowpipe Tip and Flame in This General Position

without allowing the front edge of the puddle to solidify and without interrupting the steady forward progress of the work. If desired a second pass can be made with the flame to smooth off the surface and to minimize grinding.

The puddle should be flowed in the direction desired by means of the pressure of the flame, not by stirring with the rod. Usually the work progresses toward the hand holding the rod, but on steel which scales badly, or on very thin sections, the backhand method (illustrated in Fig. 9) is sometimes used. With this method, the work progresses toward the hand holding the blowpipe. The welding operator can determine with practice the preferable method for any particular job.

If any dirt or scale appears on the steel or in the puddle, float it to the surface with the flame If it will not float, dislodge it with the rod. In extreme cases, it may be necessary to use a good cast-iron welding flux.

Fig. 6—Excess Acetylene Flame Used for All Hard-Facing Operations. An Excess Acetylene Flame Is Used to Produce "Sweating" Before the Hard-Facing Alloy Is Applied

Cooling the Deposit

Step No. 7.—When the hard-facing deposit has been built up to the desired size and thickness, remove the flame slowly from the puddle to prevent the formation of shrinkage cracks or blowholes. If these are present, remelt the deposit in their immediate vicinity, flick any particles of scale or oxide from the pool with the rod and add a little more hard-facing alloy from the welding rod. If the holes still appear, it may be necessary to grind off the alloy deposit down to the steel at that point, warm the area gradually with the flame and deposit additional hard-facing alloy there. As soon as the deposit has cooled below a red heat, it is often advisable to place the entire part in a box of powdered mica, lime, ashes or other similar heat-insulating material so that it will cool slowly.

In many cases, slow cooling is absolutely essential to produce a deposit free from cracks and internal stresses. Parts which show a strong tendency to crack, such as large gate valve wedges and seat rings, pump shaft sleeves or parts on which the deposit is circular or large in area, should preferably be placed in a heat-treating furnace while still hot from welding, brought slowly to a low red heat (about 1150° F.), and then allowed to cool overnight in the furnace with the door closed and the heat turned off. *Never cool a part by dipping it in water.*

Finishing the Deposit

Step No. 8.—After the hard-faced part has cooled, it may be necessary to remove the high spots or grind the hard-faced surface to an exact size. This is done by hand, or on a grinding machine. Any soft grade vitrified wheel, not coarser than 46 or finer than 60 in Grade I or J, is suitable for grinding. The wheel speed should not be less than 3000 nor more than 4500 surface ft. per min. Higher speeds are apt to check the work.

Fig. 7—The Welding Rod Should Be Brought Into the Flame Only after Part of the Steel Surface Has Begun to "Sweat"

Welding Tip Size

The best blowpipe tip size to use for average work is one having a consumption of approximately 20 cu. ft. of oxygen per hr. and 23 cu. ft. of acetylene per hr. For small parts, a tip one size smaller should be used; and for large, heavy parts, a size larger. The welding operator will be able to judge the proper tip size for each job very easily after he has hard-faced a few parts. It is better, however, to use a tip which allows slow, careful deposition without overheating the steel than to use a large tip and try for too much speed.

Fig. 8—The Deposit Should Be Built Up to the Desired Thickness in One Operation

Drawing Out Rod

In some cases, especially when applying the cobalt-chromium-tungsten hard-facing alloys to small areas or parts, it is best to use a welding rod of $^1/_8$ or $^3/_{16}$ in. diameter. If the smaller diameter rods are not available, $^3/_8$ or $^5/_{16}$ in. rod can be "drawn out" to the smaller size. To do this, melt one end of the rod with the usual excess acetylene flame, and lay the first drop on a cold plate of carbon, graphite, iron or steel. With the flame playing on the end of the rod and melting it, and the end of the rod touching the plate, draw the rod along the plate at a steady rate, leaving a newly formed rod of smaller diameter ready for use. See Fig. 12.

Grades of Hard-Facing Alloy

There are three grades of the cobalt-chromium-tungsten hard-facing alloy. The three grades are known as No. 1, No. 12 and No 6. This is the order of their hardness and resistance to wear.

Grade No. 1 is the hardest of the three grades and is more resistant to abrasion than Grades 12 and 6. Its hardness when welded is C-54 Rockwell; its tensile strength is 54,000 lb. per sq. in.; elongation nil. Extreme pressure or heavy shocks are liable to check or chip it, but when it is properly backed up and supported, no trouble will be experienced with it. This grade should be used for coating surfaces subjected to extreme abrasive wear and only little shock or impact.

Grade No. 12 is not quite so hard as Grade No. 1 and is slightly less resistant to abrasion. It is, however, much stronger and somewhat more ductile and, therefore, should be used for coating fairly large areas where hair-line cracks would interfere with efficient operation. It

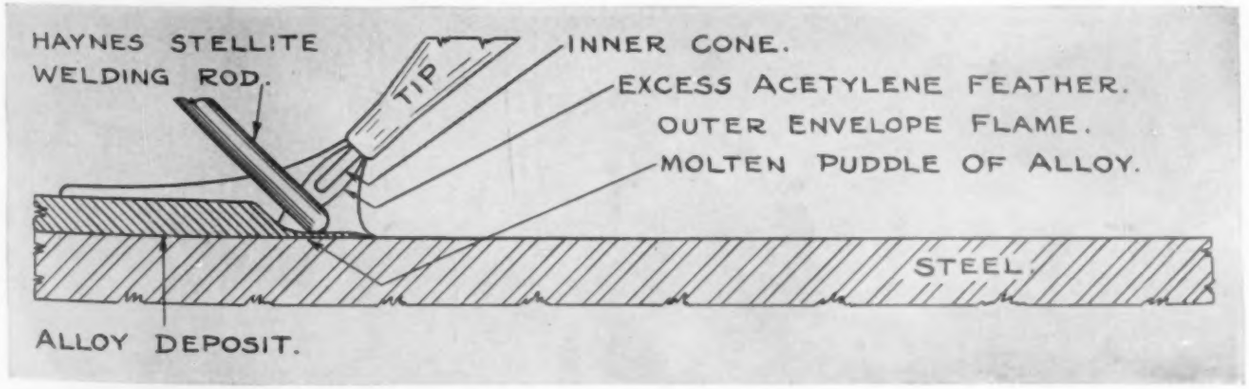


Fig. 9—The Backhand Method of Hard-Facing. The Approximate Relationship of Tip, Rod, Deposit, Puddle and Base Metal During Hard-Facing by This Method Is Shown

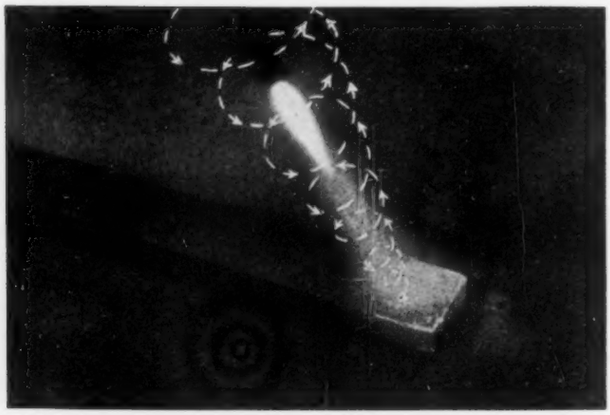


Fig. 10—The Flame Should Be Removed Slowly from the Puddle to Prevent the Formation of Shrinkage Cracks or Small Holes and with the General Motion and Direction Indicated by the Arrows

will withstand more shock and impact than Grade No. 1. This grade has a hardness when welded of C-48 Rockwell and a tensile strength of 99,000 lb. per sq. in.

Grade No. 6 is not quite as hard, but is considerably tougher and stronger than Grades 12 and 1. While it is tougher than Grades 12 and 1 its resistance to abrasive wear is slightly lower. It does not check or chip easily and is recommended for coating surfaces subjected to shock or impact and wherever a keen cutting edge is necessary such as hot shearing and blanking dies and valve seating surfaces of all kinds. Its hardness when welded is C-40 Rockwell; its tensile strength is 110,000 lb. per sq. in.

The selection of a suitable base metal is important. Although plain carbon steel is excellent for many purposes, for parts subjected to shock and impact, such as hot and cold trimming dies, SAE 3140 steel has proved to be a particularly ideal base material. This steel will not mushroom under impact since it can be given its standard heat-treatment after hard-facing.

Important Suggestions

The following list will serve as a partial check on some of the more important points above. Welding operators should thoroughly familiarize themselves with these points before going ahead with any hard-facing job.

1. Thoroughly clean a steel surface before trying to hard-face it.
2. Be sure to observe preheating precautions as required by the size or shape of the part.
3. Always use an excess acetylene feather three times the length of the inner cone as shown in Fig. 6. Never use a neutral or oxidizing flame for Haynes Stelliting.
4. Do not try to apply hard-facing alloy to steel before the surface of the steel reaches the full "sweating" temperature. (See Steps 3 and 4.)
5. The tip of the inner cone of the flame should *almost touch* the welding rod. Do not hold the flame too far away from the rod and steel surface.
6. Float foreign particles and remove them before depositing any more alloy. Never cover them over or embed them in the deposit. They may cause blowholes or porosity.
7. Spread the molten puddle with the flame. Do not puddle it with the welding rod.
8. It is usually possible to build it up to the desired thickness in one operation. Do not deposit the alloy in successive layers unless absolutely necessary.
9. Observe the cooling precautions in Step No. 7. Do not allow the hard-faced part to cool too quickly.

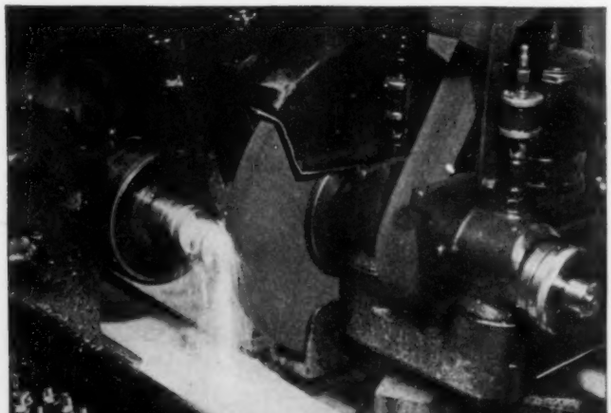


Fig. 11—The Hard-Faced Part Can Be Finished by Grinding, Either by Hand, or on a Grinding Machine, as Shown

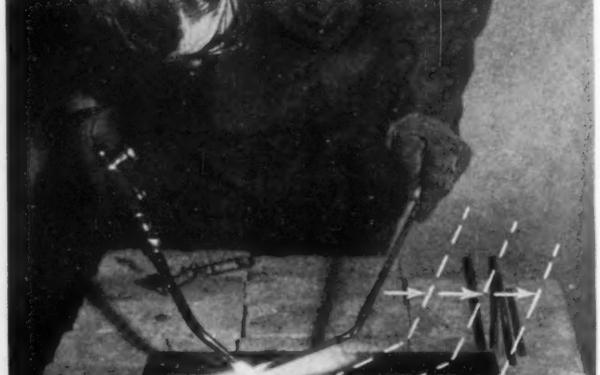


Fig. 12—Hard-Surfacing Rod Can Be Drawn Out to Smaller Diameter. The Lines Indicate Consecutive Relative Positions and Motion of Rod During Drawing

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

A Letter to the Members of the American Welding Society

My letter missed the February issue of the JOURNAL by a matter of hours, and I am sorry because I think you would have been interested in the things I had to say about the enticing south. I mailed the letter to my office, from Florida, with instructions to type and send it on to New York. However, the editor got away one mail ahead of its arrival and so, in case you were interested enough to look for a message from me in February, you'll know that it wasn't forgotten.

Last month's letter was a bit off the beaten path. I was not on the job from the first week in January until the first week in March, with the exception of a few days, and so there wasn't much from the Society's standpoint that I had to tell you. This period was a mixture of delightful experiences, decidedly undelightful ones, and ended with three weeks which should have been enjoyable, had the "don'ts" been less extensive and the longing to get back on the job less intense.

The week I spent in New Orleans, ostensibly to attend the American Road Builders Convention, was a real treat—perfect weather, enjoyable golf, excellent food in the French quarter and the joy of seeing that section as it could only be seen by being personally conducted by a charming lady who had the entree into many old homes with all the charm of their original furniture and furnishings.

I was home one week, and then, out of a clear sky, preceded by what I thought was only a mild green-apple stomachache, came the command to go immediately to the hospital and have it out. Thanks to Mr. Bibber, the competent Welding Engineer of Carnegie-Illinois, who pinch-hit for me at the February meeting of the Pittsburgh Section of the AMERICAN WELDING SOCIETY and at the Ohio State University Welding Conference, I relinquished my part in those programs, feeling that the audience benefited by my forced absence.

At long last—I like that expression; thank you, Mr. Windsor—the nearly two weeks of hospital confinement drew to an end and I was ordered off to South America for a month. I am not, as some of you know, a very patient person, and the thought of spending a month in a deck chair had little appeal. I vetoed South America in favor of Florida; at least there I could swim and lie in the glorious sunshine, although golf and sea fishing were tabooed as being too strenuous and liable to necessitate another series of belt clips. Ever see them? Just like those steel things used to fasten the ends of leather belts.

Strange as it may seem (you see this wasn't my first trip south, and previously I had enjoyed every minute there) after the first few days I started crossing them off the calendar in my impatience to get back on the job. It is the part of prudence not to tempt fate by letting things carry on too long without being on the job. Suppose everything didn't get into sixes and sevens? All of which goes to show that worry never gets one anywhere. Believe it or not, they voted me into the top job at the office while I was away.

In Florida I had two telegrams, one, an invitation to attend the dinner meeting installing the new Kansas City Section of the Society; the other to speak before the reorganization meeting of the Buffalo Section. The long trip of forty hours to Kansas City and back was worth the effort to meet with that fine, enthusiastic body of men who make up this new section. Their city, although not the largest center of welding in the country, makes up for its lack of numbers by an enthusiasm and a determination to build their new section into one of the outstanding ones in the Society. They started with fifty members, added ten more at the dinner, and if I am any judge of men, this man Dickens, prime mover in their membership committee, will make real progress.

The week following the Kansas City meeting, I went to Buffalo with Mr. E. W. P. Smith, Welding Engineer of Lincoln, to jointly put on the program for an enthusiastic meeting of over 125 men. Thanks to Mr. Smith's splendid ability as a speaker and his interesting talk on stress concentrations, illustrated with polarized light and bakelite and plastic specimens, the meeting was very much of a success. Mr. Korn, an energetic Consulting Engineer of Buffalo, and active in establishing this section, introduced us and spoke very effectively of the desirability of establishing a group in Buffalo. I came away with the impression that a section there is assured. A series of meetings is being arranged which will be addressed by outstanding leaders in welding. Certainly there is sufficient welding activity in the Buffalo-Niagara Falls district to splendidly support a section.

Word has just come to me from the New York headquarters that the Los Angeles Section under the able direction of Mr. Turner C. Smith has just completed a splendid piece of work with its lecture course on "Fundamentals of Structural Welding." Imagine, ninety new members added! Other applications came directly to New York. Now, Cleveland, Detroit, Milwaukee, Chicago, Pittsburgh and Philadelphia, what have you to say? Congratulations, Los Angeles; congratulations Mr. Smith and the boys in Los Angeles; we are proud of your work and mighty thankful for your support.

Our progress in extending our membership during this last six months has been most encouraging. Regardless of the efforts of those handful of men who are giving so much effort and time to the growth of the Society, our progress is a direct measure of the effort of the rank and file of the Society. Mr. Davis, our National Membership Chairman, and I are proud of the support given by all the sections. Just look at these results: October 64, November 93, December 116, January 89, February 88, March 187—a total in six months of 637. Of this number 20 represent sustaining members ($100 a year dues). That is a splendid showing. I hesitate to state my objective in general membership, sustaining members and new sections. I will say I believe that within the next three years we will have arrived at the position where the extent of the interest in welding and the growth and activities of the AMERICAN WELDING SOCIETY will not only tremendously increase our knowledge of the science and art of welding, but the importance of the Society to American Industry will be unquestioned. This is the objective which we seek. The attainment of it will bring in its wake a widened horizon for everyone connected with welding. Your progress, and the progress of the institution with which you are connected is vitally concerned. With so little effort you can speed the progress. I am confident of your continued interest and help. To those of you who have not done so, may I suggest: Get your man, your new member, this month!

Sincerely yours,

A. E. Gibson, President

Lecture Course Huge Success

The AMERICAN WELDING SOCIETY offers its congratulations and deep gratitude to the Los Angeles Section in arranging an unusually successful lecture course. This course was described in a previous issue of the JOURNAL. There was an enrollment of 112 and 90 became members of the Society.

New Offices

The AMERICAN WELDING SOCIETY has taken larger office space in the Engineering Societies Building on the 16th floor. Members of the Society who can conveniently do so are invited to call and inspect the new quarters of the Society.

Lincoln Prize Papers

In the previous issue of the Journal there was announced the rules for the prizes to be distributed by the James F. Lincoln Arc Welding Foundation in connection with their prize contest for welding papers. These prizes will undoubtedly serve to attract general attention to the growing importance of welding and its universal application in all fields of metal fabrication. It accomplishes another very important purpose. Welding cannot be used economically or at times with safety by merely specifying the use of welding in designs intended primarily for other methods such as riveting or casting. Some of the, present construction practices represent attempts to overcome difficulties, while others result from peculiar limitations. These same difficulties and limitations may not be effective when a totally different method, such as welding, is used. On the other hand, welding sometimes introduces new difficulties and new precautions and procedures will be needed to overcome this.

The papers will serve to promote progress in specific fields by combining the knowledge of the welding engineer with the specialized knowledge of the experts in the respective fields.

Charles E. MacQuigg

Charles E. MacQuigg, for many years research metallurgist and manager of the Union Carbide and Carbon Research Laboratories, Inc., New York City, has been appointed dean of the college of engineering, and director of the engineering experiment station of Ohio State University, to assume his new duties about July 1. Prior to his former association he had been with the Anaconda Copper Mining Co. in Great Falls, Mont., and with the Santa Fe Railroad in Texas. He served also for a considerable time as professor of metallurgy and head of the department of metallurgy of the school of mines, Pennsylvania State College. During the World War he was in the U. S. Army Ordinance Department and responsible for the inspection of all materials for the small arms program. In going to Ohio State he is returning to his alma mater. Of recent years, Mr. MacQuigg has been especially active in the engineering development of ferrous alloys and in their application to extreme conditions of service; namely, in the fields of high-temperature, high-pressure power development and chemical engineering; and in the adaptation of improved engineering alloys to the saving of weight in all modes of transportation.

Symposium on Radiography and X-Ray Diffraction Methods

The twelve extensive technical papers and large amount of discussion comprising the Symposium on Radiography and X-ray Diffraction Methods were prepared by outstanding authorities in the field. Six of the papers deal with radiography, covering principles, foundry applications, radiography in the welding shop, miscellaneous applications of radiography and fluoroscopy, radiographic specifications and gamma-ray radiography and its relation to X-ray radiography. An appendix to this latter paper provides instructions for radiography with radium. Authors of the papers in this section include: John T. Norton, Earnshaw Cook, J. C. Hodge, Herman E. Seeman, H. H. Lester and Norman L. Mochel.

The six papers devoted to diffraction cover equipment and methods, constitution of alloys, chemical analysis, determination of particle size, applications to non-metallic materials, and to problems of cold work, preferred orientations, and recrystallization. Authors in this section include: Charles S. Barrett, Kent R. Van Horn, Wheeler P. Davey, John T. Norton, G. Harvey Cameron and George L. Clark.

The symposium was developed by a committee headed by Dr. R. F. Mehl, with the close cooperation of Doctors H. H. Lester, John T. Norton and C. S. Barrett. The final symposium held in four sessions of the 1936 A. S. T. M. annual meeting was preceded by a preliminary symposium at which many workers presented results of their work with special emphasis on case histories of successful applications. All of this material was available to the authors of the final papers.

The publication is profusely illustrated —145 halftones and 50 line cuts adding to the utility of the publications, which covers 350 pages. Copies in cloth binding can be obtained from A. S. T. M. Headquarters, 260 S. Broad St., Philadelphia at $4 each.

Bridge Specifications

(*Taken from Annual Review number of Engineering News-Record, February 4, 1937*)

An important development during the year was the publication by the AMERICAN WELDING SOCIETY of its specifications for highway and railway bridges. A small welded double-track single-leaf bascule of 54-ft. span was built on the Florida East Coast Railway at Jupiter, Florida.

. . . but also the commonly-neglected factors such as endurance limit, fatigue strength, surface conditions and stress-raisers. The question of fatigue, which ordinarily is of little importance but may be the controlling factor under certain stress conditions and for certain materials, merits special study. It is to be noted that the new specifications of the AMERICAN WELDING SOCIETY give this factor due consideration.

Institute of Welding

The Official Bulletin of the Standing International Committee on Acetylene, Gas Welding and Associated Industries announces that the French firm L'Air Liquide has undertaken to compile a welding dictionary in several languages. Lists of French welding terms have been sent to other countries to obtain corresponding terms in the respective languages.

Committee on Nomenclature, Definitions and Symbols

(*Reorganized February 17, 1937*)

James W. Owens (*Chairman*), Fairbanks, Morse & Company, Beloit, Wisconsin

#*L. C. Bibber (*Chairman*, Subcommittee on Symbols), Carnegie-Illinois Steel Corp., Carnegie Bldg., Pittsburgh, Pa.

#*R. W. Clark (*Chairman*, Subcommittee on Definitions and Chart), General Electric Co., Schenectady, N. Y.

*H. O. Hill (*Secretary*), Bethlehem Steel Company, Bethlehem, Pa.

*W. A. Bischoff, Bell Telephone Labs., 463 West Street, New York, N. Y.

A. B. S. Kvall (*Alternate*), Bell Telephone Labs., 463 West Street, New York, N. Y.

*H. C. Boardman, Chicago Bridge & Iron Works, 1305 West 105th Street, Chicago, Illinois

*A. M. Candy, Hollup Corporation, 3357 West 47th Place, Chicago, Illinois

#J. J. Crowe, Air Reduction Sales Company, 100 Forrest Street, Jersey City, N. J.

#J. H. Deppeler, Metal & Thermit Corporation, 120 Broadway, New York, N. Y.

#Leo Edelson, Handy & Harman Company, 82 Fulton Street, New York, N. Y.

*C. H. Jennings, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

#*Geo. Mikhalapov, Heintz Mfg. Company, Front & Olney Sts., Philadelphia, Pa.

#*Navy Dept., Bureau of Construction & Repairs, Washington, D. C.

#Navy Dept., Bureau of Ordnance, Naval Gun Factory (C. M. Underwood), Washington, D. C.

#*C. W. Obert, Union Carbide & Carbon Research Labs., 30 East 42nd St., New York

*H. M. Priest, Railroad Research Bureau, Frick Bldg., Pittsburgh, Pa.

* Members of Subcommittee on Symbols.
# Members of Subcommittee on Definitions and Chart.

Personnel of Committee on Revision of By-Laws

J. H. Deppeler (*Chairman*), Metal & Thermit Corporation, 120 Broadway, New York

J. J. Crowe, Air Reduction Sales Company, 100 Forrest St., Jersey City, N. J.

E. M. T. Ryder, Third Avenue Railway System, 2396 Third Avenue, N. Y.

Representatives from Sections

H. A. Sweet, Associated Factory Mutual Fire Ins. Co., 184 High Street, Boston, Mass.

H. C. Boardman, Chicago Bridge & Iron Works, 1305 West 105th St., Chicago, Illinois

E. R. Benedict, Contract Welders, Inc., 2445 East 79th Street, Cleveland, Ohio

R. P. Bailey, General Electric Company, 5950 Third Avenue, Detroit, Michigan

L. L. Kramer, Kansas City Structural Steel Co., 2607 Tracey, Kansas City, Mo.

M. H. Turner, Home Oxygen Service. P. O. Box 349, Huntington Park Calif.

Bela Ronay, Experiment & Engrg. Sta., U. S. Naval Academy, Annapolis, Md.

J. J. Chyle, A. O. Smith Corporation, Milwaukee, Wisconsin

Allen W. Bates, Apt. 4503 D, Fort Peck, Montana

Milton Male, U. S. Steel Corporation 71 Broadway, New York, N. Y.

L. R. Leveen, General Electric Company Schenectady, N. Y.

W. F. Carson, Carson & Carson, 508 Commercial Trust Bldg. Philadelphia, Pa.

E. J. W. Egger, The Linde Air Products Co., 305 Ross Street, Pittsburgh, Pa.

G. C. Dierking, Steel Tank & Pipe Company, P. O. Box 1899, Sta. F., Portland, Oregon

K. V. King, Standard Oil Company 100 Bush Street, San Francisco, Calif.

Traymore Selected as Convention Headquarters

Headquarters for the Society during the annual meeting at Atlantic City in October will be the Hotel Traymore. Well adapted to convention requirements, and centrally located on the famous boardwalk, the Traymore has more than adequate facilities for technical sessions, committee meetings and entertainment. Only 450 rooms, however, ranging in rates from four to six dollars for single rooms and from six dollars to twelve dollars for double rooms are available and it is urged that Society members place reservations as early as possible.

This year's exposition, of which the Society is a joint sponsor with the American Society for Metals, is to be held as customary in conjunction with the annual meeting and promises to be outstanding both in number and size of exhibits. Makers of welding equipment and supplies are planning interesting and instructive displays and fabricators will find it well worth while to show examples of their welded products.

University of Kansas Conference

The Third Annual Welding Conference of the University of Kansas was held on March 18th and 19th. The program included the following:

Thursday Morning, March 18th

Auditorium, Central Administration Bldg.

9:00 Registration. Chairman, Prof. F. A. Russell.
A Word of Greeting: Dr. E. H. Lindley, Chancellor University of Kansas, introduced by Prof. F. A. Russell, Chairman School of Engineering.

9:30 Modernizing with Welding: Mr. W. M. B. Brady, Welding Engineer, General Electric Company, Chicago, Ill.

10:15 Electrode Coatings. Mr. F. Aschenbrenner, Head, Research Dept., Wilson Welder & Metal Co., New York, N. Y.

11:00 Principles of Surfacing by Welding: Mr. C. B. Herrick, The Lincoln Electric Company, Kansas City, Mo.

Afternoon

Chairman, Mr. Clarence S. Jones, Asst. Engineer, Missouri Valley Bridge and Iron Company, Leavenworth Kan.

1:30 The AMERICAN WELDING SOCIETY and Its Purpose in This Section: Mr. J. A. Hall, Engineer of Plate and Tank Construction, Kansas City Structural Steel Company, Kansas City, Kan.,—Vice-President, Kansas City Section, A.W.S.

1:45 Developments in Cutting of Metals by the Oxy-Acetylene Process: Mr. F. C. Hutchinson, Development Engineer, Linde Air Products Co.

2:30 Power Plant Piping: Mr. A. N. Kugler, Head, Dept. of Pipe Welding, Air Reduction Sales Company, New York, N. Y.

3:15 Manufacturing and Application of Welding Pipe Fittings: Mr. F. C. Fantz, Vice-President, Midwest Piping and Supply Co., St. Louis, Mo.

4:00 Inspection of Welding Equipment on Exhibition in Fowler Shops.

Evening, Fowler Shops

7:30 Latest Developments of the Oxy-Acetylene Process Including Welding of Power Plant Piping: Mr. G. F. Dickins, Manager, Air Reduction Sales Company, Kansas City, Mo.

8:15 Inspection of Welding Equipment on Exhibition in Fowler Shops.

Friday Morning, March 19th

Auditorium, Central Administration Bldg.

Chairman Mr. C. W. Frick, Superintendent, Standard Steel Works, North Kansas City, Mo.

8:00 Roundtable Discussion of Courses in Welding Design and Welding Technique for Engineering Students.

9:30 The Application of Welding to Petroleum Vessels: Mr. G. Raymond, Chief Engineer, Black, Sivalls & Bryson, Inc., Oklahoma City, Okla.

10:15 Facts for Beginners in Welding Engineering: Mr. E. D. Soderstrom, Assoc. Prof., Division of Engineering, Oklahoma A. & M. College, Stillwater, Okla.

11:00 Highway Bridge Welding: Mr. LaMotte Grover, Office Bridge Engineer, Kansas State Highway Commission, Topeka, Kan.

Afternoon

1:30 Chairman Mr. C. E. Woodman, Purchasing Agent, Kansas City Bridge Company—President, Kansas City Section, A.W.S.—Membership in the AMERICAN WELDING SOCIETY.

1:45 Welding Fabrication of Steel Alloy and Non-Ferrous Metal Tanks: Mr. Wm. Anderson, Supt., Columbia Steel Tank Company, Kansas City, Mo.

2:30 Welding and Brazing of Copper and Copper Alloys: Mr. W. C. Swift, Engineer, The American Brass Company, Kenosha, Wis.

3:15 Discussion on Containers for Liquefied Petroleum Gases: Mr. Ed H. Gill, Chief Engineer, Columbia Steel Tank Company Kansas City Mo.

Evening, Fowler Shops

7:00 Inspection of Welding Equipment on Exhibition.

SECTION ACTIVITIES

BOSTON

Mr. N. L. Mochel, Metallurgical Engineer of the South Philadelphia Works of the Westinghouse Electric & Manufacturing Company spoke at the January 22 meeting of the Section on two subjects—"Fabrication of the 200 In. Telescope for the Palomar Observatory" and "Some Westinghouse Welding Experiences." The first talk was illustrated.

At the February 19th meeting of the Section, Mr. W. D. Halsey of the Hartford Boiler Inspection and Insurance Company gave an illustrated talk on "Investigating of Welding from an Insurance Company's Angle." When Mr. Halsey concluded the meeting was opened for general discussion which lasted about one hour.

On March 19th, the Boston Section held a second afternoon and evening meeting at the Watertown Arsenal. At this meeting emphasis was given welding, radiographic inspection, and stress-relieving, as well as an exhibition of welded structures. Prof. H. R. Bullock of M.I.T. discussed "Bend Tests, Micro Inspection and other Important Tests." Dr John T. Norton, also of M.I.T., then spoke on "Radiographic Inspection," and Mr. H. C. Mann Senior Materials Engineer at the Watertown Arsenal, discussed "Tension and Impact Testing." Each speaker used lantern slides effectively in connection with his talk.

About 100 persons took advantage of the invitation of Col. Jenks to visit the Arsenal before this meeting, and the Boston Section is indebted to him for the opportunity of meeting there.

The annual meeting of the Boston Section will be held on April 9th at 7:30 P.M. in the rooms at 715 Tremont Temple, Boston.

CHICAGO

The regular monthly meeting of the Chicago Section was held on March 19th. Mr. H. J. Shifflie, Welding Engineer,

American Steel Foundries, spoke on "The Use of Castings in the Assembly of Heavy Welded Sections;" and Mr. J. J. Gordon, Welding Fabrication Division, Taylor-Winfield Corp., spoke on "Assembly of Heavy Sections by Welding," with motion pictures showing production of heavy equipment.

DETROIT

On Friday, March 26th, Mr. T. C. Fockler of the Westinghouse Electric and Manufacturing Company addressed the Detroit Section of AMERICAN WELDING SOCIETY on the subject: "Welded Machine Designs." An invitation was extended to members of the American Society of Tool Engineers to attend, as the subject is of interest to them as well as to the welding industry. The attendance was approximately 200. Chairman of the meeting was Mr. R. R. Bozell, of Whitehead and Kales Company. Through the courtesy of this Company, a welded machine base was on exhibition. Mr. T. Johnston, also of Whitehead and Kales Company, presented a prepared discussion of the paper, and there was considerable extemporaneous discussion.

Plans for the April meeting are not sufficiently far advanced for announcement.

The May meeting will be in the form of a joint session on welding with the A.S.-M.E., in connection with A.S.M.E.'s semi-annual meeting in Detroit.

KANSAS CITY

The organization meeting of the Kansas City Section was held on March 1st in the Kansas City Power and Light Building. Mr. C. E. Woodman acted as Temporary Chairman. Mr. Woodman reported that more than 33 members made application to join the Society. Mr. A. W. Roth was appointed Secretary. A Nominating Committee was appointed with the following members: C. W. Frick, L. R. St. John, George F. Dickins, Clayton B. Herrick, Ralph E. Koons, Prof. A. H. Sluss and J. A. Hall.

This resulted in the election of the following officers for the ensuing year.

Chairman—C. E. Woodman
Vice-Chairman—J. A. Hall
Treasurer—John Colver
Secretary—Albert W. Roth

The following members were elected to serve on the Executive Committee, representing the consumers for one year: LaMotte Grover, Prof. A. H. Sluss and Walter H. Kurtz.

For two years: N. R. Sack, L. L. Cramer and C. W. Frick.

Members representing Manufacturers of Welding Apparatus were elected to serve, they to appoint their own representative, for one year: Linde Air, Puritan Compressed Gas and Harnischfeger.

For two years: Air Reduction Sales Co., Lincoln Electric and General Electric.

The Chairman appointed the By-Laws Committee consisting of: L. L. Cramer, Chairman, C. W. Frick and Ralph E. Koons.

Mr. Norman Sack of the Missouri State Highway Department gave a short talk on the problems of electrodes from the standpoint of the Inspection and Engineering Department of the Highway Department.

The first formal meeting was held on March 13th, preceded by a banquet. At this meeting there was reported that 50 members joined the Society.

Mr. Gibson presented a complete account of the Society activities and the advantages of affiliation with the Society.

LOS ANGELES

The regular meeting was held March 18th at the Central Manufacturing District Club Rooms with 90 members and guests present. Dinner was served at 6:30 P.M. after which the meeting was called to order by Chairman Wayne Howard. Guests were introduced and minutes of the previous meeting read and approved.

Mr. Zeno Klinker, humorous writer and aviation enthusiast, presented "Man's Conquest of the Air." This is a motion picture which is the most complete and comprehensive collection of authentic historical aviation films in the world. It was completed by Mr. Klinker after thirteen years of research for such films.

Mr. Bruce Burns, Consulting Aircraft Engineer, then spoke on "Aircraft Spot Welding of Aluminum Alloys and Corrosion-Resisting Steels." The material for Mr. Burns' paper was collected during actual fabrication at the Northrop Corporation. The talk was illustrated with slides.

The third speaker was Mr. B. J. Brugge, who presented a review of the current issue of THE WELDING JOURNAL.

Mr. Turner Smith, Regional Vice-President, then lead a discussion of the American Welding Society's Code for the Qualification of Welding Processes and of Welding Operators. This topic was discussed in an attempt to offer the Section's recommendation to the national organization.

There being no further business, the meeting was adjourned.

MARYLAND

The regular meeting of the Maryland Section was held at The Engineers' Club of Baltimore on March 19th and was well attended. 85 members and guests were present. Mr. W. C. Stewart, Senior Metallurgist, U. S. Naval Engineering Experiment Station, Annapolis, spoke on "Metal Spraying, Applications and Properties." The lecture was illustrated by slides.

MILWAUKEE

A joint meeting of the Milwaukee Section of the AMERICAN WELDING SOCIETY with the American Society of Civil Engineers was held on Tuesday, March 30th at the City Club of Milwaukee. The speaker of the evening was Mr. A. M. Candy, Consulting Engineer, Hollup Corp., who spoke on "Arc Welding in Structural Engineering."

MONTANA

At the March 3rd meeting of the Montana Section a talk was given by Mr. Roy L. Lerch, Sales Manager of the Haynes Stellite Company, entitled "Hard Surfacing Wearing Parts." Included in Mr. Lerch's talk was a paper by E. E. LeVan, entitled "Hard Facing." The meeting was well attended and the Section presented its hearty thanks to Mr. Lerch for contributing so freely of his time and energy toward the success of the meeting.

NEW YORK

A joint meeting of the New York Sections of the AMERICAN WELDING SOCIETY and American Society for Metals will be held on Monday, April 19th at 8 P.M. in the Metal Products Exhibit Hall, Third Floor, International Building, Rockefeller Center. Mr. Everett Chapman, President of Lukenweld, Inc., will address the meeting on "Stresses in Welds and Their Elimination."

The May meeting will be held on the 11th and will be an annual business meeting at which motion pictures showing new developments in welding and cutting will be shown.

PHILADELPHIA

The Philadelphia Section held a very interesting meeting on March 15th at which Mr. Chas. H. Jennings of the Westinghouse Elec. & Mfg. Company, gave an excellent talk on "Solving Manufacturing Problems by Welding."

The following Officers and Executive Committee have been elected:

Chairman—T. M. Jackson
Vice-Chairman—E. G. Hosted
Treasurer—R. D. Thomas
Secretary—H. E. Hopkins

Executive Committee: J. W. Allison, H. R. Salisbury, W. F. Carson.

On Monday, April 19th, Mr. T. R. Lichtenwalter of The Republic Steel Corporation will present an address on "Manufacture, Uses and Applications of Enduro Stainless Steel." Sound Motion pictures will also be shown.

The closing meeting of the Spring Series which will be held in May will be devoted to an interesting inspection trip through a large plant in the Philadelphia area where welding is a major activity. Announcement of date and plant to be visited will be made soon.

PITTSBURGH

One of the most successful meetings of the 1936–37 season was held on March 17th in the Roosevelt Hotel when Mr. G. O. Carter, Consulting Engineer of The Linde Air Products Co., addressed the Section on the general subject of "The Past and Future of Welding in the Pittsburgh District." Mr. Carter gave a very interesting and entertaining address on a subject which only one in his position would be in a position to properly cover. Taking the weld art from the very beginning in the Pittsburgh district, Mr. Carter worked through the various departments and phases up to and including the present time and then went on to predict some of the conditions which might be expected to arise in the future and some of the ob-

stacles that would necessarily have to be surmounted.

Over one hundred persons interested in welding were present. Following Mr. Carter's address, the meeting was thrown open for an open discussion. Mr. Carter was given a rising vote of thanks for his treatment of the subject.

The next regular meeting of the Pittsburgh Section will be held Wednesday night, April 21st at 8:00 o'clock in the Roosevelt Hotel. The speaker of the evening will be Mr. R. B. Lincoln, Director of the National Welding Testing Bureau. Mr. Lincoln will address the Section on "Safety in Welding."

SAN FRANCISCO

The March meeting of the San Francisco Section was postponed until April 2nd. Mr. W. E. Emmett, District Engineer of the American Structural Steel Association, the main speaker, presented an address on "The Welding of Structural Shapes in Buildings and Bridges."

WESTERN NEW YORK

A reorganization meeting, the first held in four years by this Section, took place at the Hotel Statler, Buffalo, Thursday, March 18th at 8 P.M. The program included an introductory address by Col. Martin P. Korn, Consulting Engineer of Buffalo and an address of welcome by A. E. Gibson, President of the Society. The principal address was an illustrated talk by E. W. P. Smith, Consulting Engineer, The Lincoln Electric Company, which included stress distribution in various kinds and types of welded joints by projecting rubber models on a screen, also by projecting celluloid models using polarized light. There were about 150 present.

EMPLOYMENT SERVICE BULLETIN

POSITION VACANT

V-78. Mining unit in Bolivia wishes to obtain services of a competent welding instructor to teach mechanics and repair men up-to-date methods and practices in both arc and gas welding. Man must be thoroughly competent as an artisan and tactful in relation to employees. Assignment is for six months and in addition to salary would pay traveling expenses and portion of living expenses.

V-79. Welder Sales Manager to take immediate charge of National welder sales organization; must have executive ability to appoint and direct sales personnel.

SERVICES AVAILABLE

A-237. Young man, age 22, was in charge of office with Electrode Manufacturer as assistant to Executive. Broad training, including several years Chemical Engineering, Cost Accounting, Typing, Machine Tool Oper., Alex. Hamilton Bus. Management. Now studying stenotypy for Secretarial work. Experience in Planning Dept., Control Lab., Factory Office. Best of references.

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